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STAR COLORS AND A METHOD OF VERIFYING THEM

C. H. GINGRICH.

In the thoughts of those who have not given especial attention to astronomy, the sun and the stars belong to two classes which are very different in many respects. The sun quite obviously is constantly changing its position of rising and setting, being much farther north in summer than in winter, while the stars seem to be stationary. The sun gives warmth and light, without which the earth would be barren and desolate, while the stars are entirely negligible in regard to the heat they send us and almost so in regard to the light. The sun presents to our view a large disk, but the stars show only a faint flickering light coming apparently from a point or at most from a very small area. It is therefore with astonishment that we learn that the sun is nothing more than one of the great host of stars that adorn the vast expanse of the cloudless, moonless sky, and that it is much smaller and much less bright intrinsically than many of the class to which it belongs. It seems so much larger and so much brighter than the other stars because of its proximity to us, and not because it is the most magnificent body in the universe.

Again, most people would doubtless say that the sun is different from the stars in the character of the light it sends. The sun shines with a decidedly yellow light while the stars shine so faintly that, if they do not all send us the same kind of light, they do not attract our attention by the preponderance of their color as the sun does with the pale gold of its rays. While, from a superficial consideration of the sky, one might assent to the above, he could not long do so after his attention had been directed to a few of the bright stars. To the naked eye there are stars which present the various colors of the spectrum from the blue to the red. The brightest star in the sky, Sirius, may be taken as representative of the class of stars which give white light. Although Ptolemy speaks of

this star as "fiery red," it is certainly very far removed now from the red. Stars of this kind are often spoken of as white stars. Sirius, indeed, sometimes seems to go beyond the ordinary white star and to show scintillations of blue. Vega, the brightest star in Lyra, Castor, one of the twins, both very bright stars, and the well known variable, Algol, are other examples of pure white stars. Mirfack, α Persei, the brightest star in Perseus, Procyon, the brightest star in Canis Minor, and Polaris, the Pole star, are examples of stars which are not pure white stars and which, on the other hand, do not exhibit any great degree of color. Proceeding in the series we find Capella, the brightest star in Auriga, showing considerable color, very similar to the pale yellow of the planet Saturn. At this stage we have stars of the same kind of light as the sun. But we have not yet come to the end of the series. Even among the bright stars there are some which shine with a decidedly red light. The most notable of this class among the bright stars are Arcturus, the brightest star in Boötes; Aldebaran, the brightest star in Taurus; Betelgeuse, the bright star in the well known constellation Orion north of the three belt stars; and Antares, the brightest star in Scorpio.

Although these different shades of color are apparent to the naked eye of any one trained even only to a slight degree in distinguishing colors, a telescope does much in the way of emphasizing the effect. It may be well, however, to caution those who are not familiar with telescopic views, that there is usually very much more color in the telescopic view of a bright star than really belongs to the star itself. It is very difficult to correct the objective lens entirely for what is called chromatic aberration. Hence there is usually seen a fringe of color, about the image of the bright stars, which has its origin in the lenses of the telescope. Some color also is due to the atmosphere of the earth.

This variety of color is characteristic not only of the naked eye stars but of the fainter stars also. Indeed some of the faint stars show much greater depths of color than the bright stars already mentioned. Hind, who first noticed the variable star, R Leporis, in 1845, said that it appeared to him like "a drop of blood on a black field." The deep red of this star changes to a fainter red, almost copper, color as the star becomes brighter. Sir John Herschel describes a star of about the eighth magnitude near the Southern Cross as of "the fullest and deepest maroon-red, the most intense blood-red of

any star I have seen. It is like a drop of blood when contrasted with the whiteness of β Crucis." These are a few of the many stars that might be mentioned as having very striking intensities of color. Many of the variable stars vary in color during their period, being more highly colored when near the minimum. The reason for this may be that the red rays are in excess and when the light of the star is diminished the rays other than the red are all absorbed in the atmosphere of the stars, the red rays only being able to escape the absorption. Temporary stars, the Novae, also manifest different colors in their development. They as a rule lose color as they become fainter, which is the reverse of the order in the case of variable stars.

We should be inclined to speak much less confidently of the different colors in the stars if we were dependent upon the eye alone for the estimates of color. Some persons have very delicate color perception while others are entirely unable to distinguish between the finer shades or may even entirely misinterpret color sensations. Such persons are said to be color blind. In a recent publication of the Potsdam Observatory in which the visual magnitudes of all the stars in the Argelander catalogues of magnitude 7.5 or brighter, 14199 in number, are given, the observers have assigned fourteen different shades of color, ranging from white to red, to the various stars in their list. Their color perception is very keen, since they are able to distinguish fourteen shades where the ordinary person could see possibly only four or five at the most. These fine distinctions might be thought to be merely imaginary if it were not possible to verify them by some means. Fortunately the color of a star is only an indication of the actual condition of the star and its atmosphere, and if two stars can be shown to differ in the character of their component materials there is then a basis for a difference of color, which difference may be apparent to the well trained eye only.

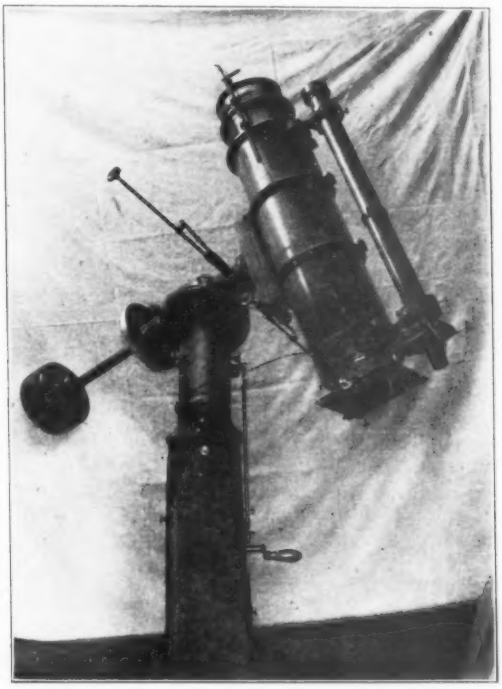
The composition of the distant stars can, indeed, be known. The breaking up, or technically the dispersion, of composite light into the various colors of the rainbow in passing through a glass prism is a well known phenomenon. The prismatic effect is different for different sources of light, and it is also modified by interposing different kinds of gases between the source of light and the prism. These varied results are well known facts in physics, and the particular result in any case points directly to definite conditions which cause it. The light from the stars, if allowed to pass through a prism, coming, as

it does from the sun, from a luminous body through the various gases in their atmosphere is obviously subjected to the same conditions as are formed in the laboratory by interposing a particular gas between the source of light and the prisms. The distance is not of any consequence since the essential elements are the light waves, which require more time to arrive from the stars than from some terrestrial point but which are not changed in character.

It remains then to collect a sufficient quantity of light from the star, let it pass through a prism and fall upon a sensitive plate and the star itself tells the story of its composition. In order to get a sufficient amount of light from the star it is necessary to gather it and to bring it to a focus by means of a telescopic lens. The light may be allowed to pass through a prism before or after it has passed through the lens and the desired dispersion will be secured in either case. In the latter case the spectrum is secured by the use of a spectroscope. The accompanying illustration (Plate XXII) shows the result of the light passing through the prism and then through the lens. The arrangement of the instrument for producing the results shown will now be described.

The prism called the "Objective Prism" is set in a cell which is of such a size as to fit exactly over the cell that contains the six-inch ultra-violet objective lens of the Zeiss camera of the Yerkes Observatory. The objective prism cell is held in place by screws and the balance of the instrument is re-established by sliding the entire tube a short distance in its cradle and by adding a counterweight to the declination axis. It can be put in place or removed in a very short time. The prism has an angle of 15° and consequently does not give so much dispersion as a prism of greater angle would give. What is lost in dispersion, however, is gained in intensity of light and the spectra of fainter stars can be secured than would be possible with greater dispersion, other things remaining the same. The prism is so placed that the spectrum of the star, which is a narrow band of colors, extends in a direction at right angles to the diurnal motion. If then the telescope is not moved while the star drifts because of the diurnal motion, the narrow spectrum can be widened to any desired extent on the photographic plate and thus be made a better image for study. If the star is faint it must be made to drift repeatedly over the same part of the plate in order to make an image.

The stars that are shown in the illustration are not found in the sky in the position that the plate would indicate. They were brought into these positions for the purpose of comparison by exposing on one of the stars and then making an entirely



THE ZEISS ULTRA VIOLET CAMERA OF YERKES OBSERVATORY.

different setting of the telescope and exposing on another. Stars 1 and 2 should be shifted slightly to the left to bring them into perfect alignment with the other three. The illustration shows the negative of the spectra and consequently the absorption lines are white and the bright parts of the spectrum are dark.

A mere glance will suffice to show marked differences in the spectra of the stars used. Algol, on this scale, shows a series of lines which are known as the hydrogen series. These are absorption lines and indicate the presence of hydrogen in the atmosphere of the star. There are numerous other lines in

the spectrum which are too fine to appear on the scale of these spectra. The hydrogen lines are designated, beginning at the right which corresponds to the red end of the spectrum, as Hα, Hβ, Hγ etc. Hα is too far in the red to appear. There is just a suggestion of Hβ, but after that the series is quite prominent until it again fades out at the blue end of the spectrum. Stars of this class are called stars of the first type. The next star, α Persei, shows the hydrogen lines very much fainter than Algol shows them and also shows some new lines.

One of these is seen just to the left of Hγ and is known as the solar G group. Another and even more prominent line appears in this star between Hε and Hζ. This is known as the K line and indicates calcium. This star is of the class F, and is intermediate between the first and second types. The next two spectra, those of Capella and of Saturn, show a marked similarity. The hydrogen series has disappeared, on the small scale of the illustration, and the solar G group and the K line have become much stronger. Also the H line, another calcium line to the right of the K line, is very prominent. These spectra are of class G, or of the second type. Stars having this spectrum are also frequently spoken of as solar type stars, because their spectra resemble closely the spectrum of the sun. It is quite natural that this should be the case because the light from Saturn, one of our examples, is reflected from the sun. The last star, Aldebaran, shows a still different spectrum. There are numerous fine lines but those that were prominent in the other stars are here very weak or entirely lacking. There is also a decided falling off in the intensity of the spectrum toward the left or violet end, showing that the great preponderance of light is in the red region. This star belongs to class K, intermediate between the second and third types.

Beyond these there are stars of still different types. They are for the most part, however, among the fainter stars. Between the examples here shown there are stars which form a continuous gradation from one type to the next. This continuity suggests very strongly progressive development, processes of evolution among the stars. The direction in which this development is moving is still subject to question. It is supposed that the white stars, those in which the hydrogen lines are prominent, are comparatively young, and that those of the later types, such as Aldebaran, have advanced much farther in their development. It may be, however, that the tendency is in exactly the opposite direction, since the changes are so

slow, according to our idea of time, that no progress has been noted in any particular star since this method of study has been employed.

Whatever direction the process is leading, since the sun does not form either extreme in the series, but occupies an intermediate stage, it is quite probable that the sun still has a long life to live, and that many, perhaps we may say countless, generations of men will pass before the sun will show signs of decline, and before it will no longer serve the earth in the same capacity as we know it now.

STAR-STREAMS AND THEIR DISTRIBUTION.

HECTOR MACPHERSON, JR., F. R. A. S.

In the early days of stellar astronomy it was firmly believed by astronomers that the stars were scattered through space with some approach to uniformity. This belief found expression in the famous disk-theory of Wright and Lambert, which the elder Herschel adopted as a probable working hypothesis in the beginning of his career. Careful and prolonged study, extending over many years convinced that greater astronomer that the disk-theory was untenable and accordingly he abandoned it altogether. It was obvious to him that that the stars were not scattered uniformly. The Milky Way was not merely a region of greater extension of the star-stratum in the line of sight; it was a region of actual clustering where the stars were actually closer together than in other parts of the Universe. The truth of this conclusion has been abundantly verified by the researches of modern astronomers, which have shown that the Milky Way is a reality, not a mere appearance.

Not only the mere clustering, but also the configuration of the stars are inexplicable on the old theory of equal distribution.

To the late Mr. Proctor and the late Mr. Gore, astronomy owes the first real recognition of the tendency of many stars to run in streams. Now there are undoubtedly many instances where what appears to be a connected stream of stars is not a stream at all: that is to say, we must remember that the stars in a given region of the heavens may be at vast distances from one another, and if two stars or more appear in a straight line one may be billions of miles nearer to us or farther from

us than the other. This must be carefully borne in mind; but at the same time it is highly improbable that in the case of even one stream such as the famous festoon or curve round Alpha Persei (Mirfak) the stars merely appear as a connected system and that they merely happen to lie in the same line of sight. If it is improbable in one case, it is altogether impossible in many cases. Some streams *may* be apparent; the large majority *must* be actual connected systems of stars.

Proctor in his discussion of the whole question of star-streaming, pointed out many years ago—"The question will at once suggest itself whether we have not been following a merely fanciful scheme, whether all these apparent streams might not very well be supposed to result from mere chance. Now from experiments I have made I am inclided to believe that in any chance distribution of points over a surface, the chance against the occurrence of a single stream as marked as that which lies along the back of Grus or as the curved stream of bright stars along Scorpio is very great indeed. And whenever one observes a tendency to stream-formation in objects apparently distributed wholly by chance, one is led to suspect and thence often to detect the operation of law."

Proctor and Gore both noted and laid stress on the streaming tendency apparent in the brighter stars. They also noted instances of star-streaming in selected regions. Many of these are mentioned by Gore in his great book "The Visible Universe."

I have very often been impressed in the course of binocular surveys with the considerable number of remarkable streams and configurations in the heavens, and especially in the galactic and semi-galactic constellations. Firstly consider the classic example, the remarkable festoon of stars round Mirfak (Alpha Persei). It is quite obvious that here we are dealing with no mere accidental projection of stars at various distances, but a true stream; similarly with the famous binocular group round Gamma Cassiopeiae, also obvious in the telescope. Here there is a complete symmetrical curve of stars of equal brightness, with Gamma, superior to all in brilliance occupying a central position.

Another striking case of streaming and clustering is the region of Deneb (Alpha Cygni), which is best studied with a binocular field-glass. In August 1904, when I first studied this region with the binocular I jotted down in my note-book—"The boundary between the galactic light and the darkness of the small rift near Alpha Cygni is marked by a stream or

line of stars which appears distinctly connected with the nebulosity. No one observing the region can believe that the fainter stars are billions of miles behind the brighter." The whole region would rather seem to be a connected system.

A striking instance of star-streaming is afforded by the region round Lambda Orionis, as seen in a 2-inch refractor. In January 1911, I noted down in my observing book—"This is a double stream, with seven stars in one arm and six in the other. There are three faint stars between two bright ones in the larger arm beautifully and symmetrically placed."

About a year ago, it occurred to me that it would be profitable to make a rapid survey of the heavens with a 2-inch refractor examining a number of regions in each constellation in order to ascertain (1) the number of streams in each constellation in a limited number of telescopic fields and (2) the distribution of such streams in the sky—whether or not they were more prevalent in the galactic region of the heavens. In many respects a 2-inch telescope, with its wide field of view, is a particularly good instrument for the purpose of a rapid survey.

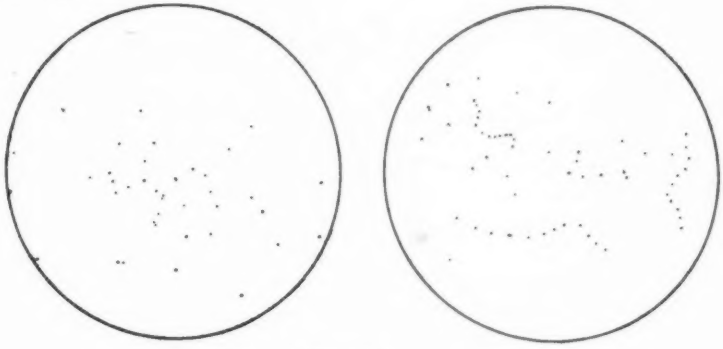


FIGURE 1.

Typical region of general scattering. Typical region of star streaming.

First of all, a definition had to be reached of what was to be regarded as a stream. Accordingly regions were divided into two classes—(1) those in which there is streaming of the stars in the region and (2) those in which the stars in the region are either very sparsely distributed or else distributed with no apparent streaming tendency (Fig. 1).

A stream is defined as a line, curve, chain, or festoon of stars, in which the imaginary line joining the individual stars is

either a straight line or a symmetrical curve. The eye soon gets accustomed to discern what is a stream and what is obviously a mere scattering. In order to ensure that only genuine cases were counted, a stream was not accepted as such unless it contained five or more stars.

The second point was the number of observations necessary. It was decided only to explore the regions surrounding the brighter stars. This secured a scattered distribution of the regions chosen for observation.

Altogether 144 regions were subjected to close scrutiny. I divided the constellations into two classes—

I. Those in which the regions containing streams were more than one-half (.5) of the regions observed.

II. Those in which the regions containing streams were less than one-half of the regions observed. This class may be further subdivided into

(i) those in which the regions observed were under one-half (.5) and over one quarter (.25)

(ii) those under one-quarter.

The statistical results of the investigation may be discussed from two points of view—

1. Proportion of star-streams in each constellation.

2. Distribution of star-streams in hours of Right Ascension.

Discussing the results from the first point of view, the constellations were divided as follows into the classes mentioned above.—

(I). Perseus, .7; Cassiopeia, .66; Cygnus, .6; Cepheus, .6; Aquila, .57; Canis Major, .5.

(II). (i) Auriga, .44; Lyra, .44; Gemini, .42; Taurus, .4; Orion, .39.

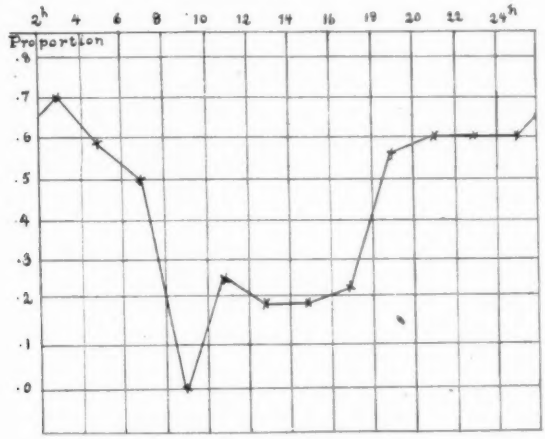
(ii) Leo, .25; Andromeda, .25; Ophiuchus, .22; Draco, .18; Hercules, .15; Pegasus, .13; Canis Minor, Ursa Major, Ursa Minor, Sagittarius, Aries, Aquarius, Canes Venatici, Capricornus, Bootes, Corona Borealis, Serpens and Cetus, .0.

The result is suggestive. Class I includes constellations immersed in the Galaxy. Class II (i) includes constellations bordering on, but not immersed in, the Galaxy—semi-galactic constellations; II (ii) includes non-galactic constellations, with one exception Sagittarius which was only very imperfectly surveyed.

Discussing the results from the second point of view, I arranged the stars in order of R. A., the hours of R. A. being taken in pairs. The largest proportion of star streams in each

two-hour space was then taken and a graph formed (Fig. II).

The graph indicates a maximum between Hours II and IV and a minimum between Hours VIII and X. The maximum



This represents the fluctuations of the maximum proportions of regions of star-streaming in hours of R. A. The maximum is reached between hours II and IV where the galaxy most nearly approaches the vertical. The miuimum is reached between hours VIII and X, near the galactic poles.

hours are galactic hours, the minimum non-galactic hours. The important fact to be noted is that the galactic hours show the largest number of star-streams in a limited number of regions of the heavens.

General Summary.

In summing up, it is to be noted, in the first place, that the investigation does not claim to be exhaustive. Only a limited number of fields, as already pointed out, were selected for study in each constellation—the regions surrounding or very close to the brighter stars. Of course it may be argued that many of the streams are apparent, but even if this were so, which is unlikely, the apparent streams will be scattered at random all over the sky and thus will neutralize each other.

In the second place, the investigation merely touches the fringe of a great and absorbing aspect of stellar astronomy—an aspect which, judging from the uncertainty of modern astronomers, is still in its infancy. I fully realize that the investigation must be vastly extended in its scope before a truly

reliable graph can be constructed or before a discussion of the distribution of star-streams in galactic latitude can be attempted; and I hope to continue the investigation further, the present paper being merely preliminary.

The results of the investigation go to prove that star-streams are not scattered at random all over the heavens, but are more numerous in the Galaxy than in the regions adjoining it, and more numerous in these regions than in the regions near to the galactic poles. In several constellations, not a single undoubted case of streaming was noted in all the regions examined; while in the galactic constellations streaming regions were the rule, not the exception.

The exact bearing of the phenomenon of star-streaming on the question of the construction of the Universe is still somewhat doubtful. Much light would probably be thrown on the constitution of the streams themselves by spectroscopic study of their spectral types and radial motions. Then all the streams visible to the eye in the telescopic field must be connected with, and form lesser members of, the great streaming systems which Professor Kapteyn's researches have disclosed. The co-relation of all the important facts now ascertained concerning star-streams, star-clustering, stellar aggregation towards the Galaxy, star-drift and the solar cluster, is the great task before the astronomers of the future.

The above investigation has not, it is true, disclosed any new truth; it can only claim to have emphasized the fact that observations with a small telescope, in regions scattered at random all over the sky, disclose clear evidence of the aggregation of star-streams towards the Galaxy, the region of streaming and clustering.

THE ISOLATION OF AN ION.

Measuring the Smallest Thing in the World.*

WILLIAM J. HUMPHREYS, U. S. WEATHER BUREAU.

Just as the accurate measurements of controlled phenomena have taught as much that is definite and much that is useful about the divisibility of matter, so also cleverly designed and skilfully executed experiments are giving as equally definite

* Reprinted from the *Scientific American*, Sept. 2, 1911.

knowledge of the atomic nature of electricity, of the fact that there is a measurable and seemingly ultimate limit to the divisibility of an electric charge, and what the exact magnitude of the ultimate charge is.

Like nearly every other discovery of importance, this one, too, has a long and an honorable history. In fact it can be traced back, step by step, almost a century.

The first, and in many ways most fruitful contribution to this subject, was made by that prince of experimenters, Michael Faraday. It consisted in proving that when an electric current is passed through a water solution of any one of certain substances, the substance itself is taken out of the solution, to an extent dependent entirely upon the quantity of electricity so passed, and upon the nature of the substance dissolved. Thus, when the same current is passed in series through the water solutions of several salts, such as sodium chloride, silver nitrate, copper sulphate, and the like, the weight of the metal deposited, or, under proper conditions, permanently removed from the solution, is directly proportional to the atomic weight of the metal itself, and inversely proportional to its valency, that is to say, to the number of hydrogen atoms necessary chemically to take the place of one atom of the metal. This proportionality between the quantity of electricity passed through the solution, and the resulting amount of chemical decomposition, holds rigidly true, within the limits of experimental error, under all conditions, and hence it seems practically certain that to each ion in a solution conveying an electric current there belongs a definite electrical charge; and that the smallest of such charges is that carried by a single hydrogen atom, or by a single atom of any other univalent substance. A bivalent atom, such as copper in copper sulphate, carries just twice the smallest, or univalent charge; a trivalent atom three times the smallest charge; and so on for atoms of still higher valency. Hence, in electrolytic solutions there is a measurable "smallest possible charge," of which larger electrolytic charges are only definite multiples.

A natural inference from these experimental facts would be (and this inference was drawn by many) that electrical charges are just as definitely atomic in their nature as, for instance, is a mass of iron. That just as, under given conditions, there is a limit to the actual, though not to the conceivable divisibility of matter, so too there is a limit to the actual, though again not to the conceivable divisibility of an electric charge. This,

however, was only an inference, and for many years the way to test it, in the case of any quantity of electricity other than that used in the decomposition of an electrolite, was not evident. Besides, even in a process of electrolysis, the most refined measurements could directly detect nothing less than the aggregate of countless millions of elementary charges, so that the value of the unit charge was only inferentially and not immediately determinable.

About a dozen years ago, J. J. Thomson, H. A. Wilson, and C. T. R. Wilson, began, in the Cavendish laboratory at Cambridge, England, a series of most ingeniously devised and skilfully executed experiments that proved the existence of minute electrical charges in conducting gases, and showed their average value to be, as nearly as could be determined, the same as that of the electrolytic charge spoken of above.

C. T. R. Wilson showed that a fog of water particles will form in dust-free air whenever the degree of super-saturation is sufficiently pronounced. If the air is ionized, or has been rendered conducting through the action of X-rays, or otherwise, then a four-fold super-saturation causes condensation of the water vapor on the negative electrons; a six-fold super-saturation gives condensation on the positive electrons; and an eight-fold on the neutral molecules of the gas itself.

Now, a knowledge of the amount of water vapor present, and of the extent of the cooling below the dew point by which the super-saturation is produced enables one easily to compute the weight of the water condensed as fog. Furthermore, if the fog is left to itself, it slowly settles at a rate which, as Stokes proved long ago, depends upon the size of the individual particles and upon the viscosity of the medium through which they fall.

A measurement, then, of the rate at which the fog falls, since it all falls at about the same rate, enables one to calculate the size of the individual particle, and this knowledge of the size of the particle, together with a knowledge of the amount of water condensed, at once gives the total number of particles.

On bringing a charged body near this electrified fog its motion is modified, and a means is at hand for measuring the magnitude of the charge of each particle. Probably the simplest method of measuring this charge, through the behavior of the fog as a whole, is that devised by H. A. Wilson. The rate of fall of the fog is measured when there is no external electric field acting on it, and thus the size and weight of the

individual particle determined. After this a vertically directed uniform electric field is brought to bear on the particles and regulated to just counteract the force of gravity, so that the fog neither rises nor falls. Under these conditions of equilibrium the value of the charge on each particle of fog, multiplied by the strength of the field, is equal to the weight, of the suspended particle, and hence when both the weight of the droplet and the strength of the field that keeps it in suspension are known, the numerical value of the charge is also known. All this, however, assumes that the rate of fall of the fog *en masse*, the group rate, is the same as would be that of a single one of its droplets if alone. This, as a matter of fact, is not rigidly true.

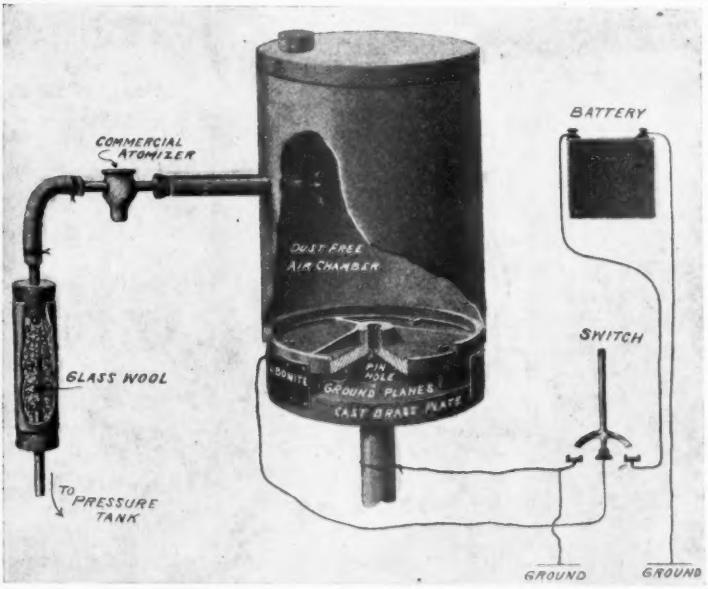
For this, and for other reasons too, it seemed extremely desirable to Professor R. A. Millikan, of the Ryerson physical laboratory, at the University of Chicago, somehow to isolate and to measure an ion entirely by itself.

PROFESSOR R. A. MILLIKAN,
Whose isolation of the ion is "one of the most important achievements of modern physics."

A few years ago it would have been almost silly even to have dreamed of accomplishing such an experimental feat. But

Professor Millikan has most cleverly solved this seemingly impossible problem, and by so doing probably has made by far the most accurate of all determinations of the value of this fundamental unit, the atom of electricity. Nor is this all, for the improved value of this unit carries with it correspondingly corrected values of other things—such as the number of atoms per unit weight of any given element, and the mass of the individual atom itself.

The full account of this ingenius and valuable investigation is given in the *Physical Review* for April of this year, and should be consulted by any one especially interested in the subject. In brief the process by which single ions were isolated and individually measured was as follows:



PROFESSOR MILLIKAN'S APPARATUS,
By which he has isolated an ion and measured its charge.

A fine spray of oil was blown by dust-free air into a dust-free chamber, the bottom of which was closed by a brass disk 22 centimeters in diameter. The center of this disk, which was perfectly plane on the underside, was pierced by a pinhole, through which an occasional oil droplet fell. Strictly parallel

to this disk, and just sixteen millimeters below it, was another brass disk of the same size. A band of thin ebonite was bound around the edges of the disks, while ebonite rods kept them fixed in position and also strictly insulated from each other. In this way a cylindrical air chamber, twenty-two centimeters in diameter and sixteen millimeters long, was formed between the two parallel brass plates.

A parallel beam of light was passed through two diametrically opposite glass-covered holes in the ebonite band, and hence immediately beneath the pinhole in the upper plate. Through a third glass-covered hole in the ebonite band a low power telescope was so focussed as to show distinctly any object floating in the air immediately beneath the pinhole. As soon as one or two droplets chanced to fall through this opening, and therefore, into the field of the telescope, it was closed by an electromagnetically operated cover, so as to prevent, as far as possible, all disturbances due to air currents. Changes in the size of the drop were almost entirely eliminated by the use of substances that evaporate slowly, and by the additional precaution of having the volume of the cylinder, through moistening its walls, already saturated with the vapor of the substance used.

The rate of fall of the droplet, due to the force of gravity alone, was measured, and in this way its size and mass approximately determined, as above explained. The plates were then charged to a known difference of electrical potential and hence the movement of the droplet, if electrified, was changed. The new velocity was measured and its direction noted. These measurements with the electric field alternately off and on were repeatedly taken, but during the course of the observations it frequently happened that the droplet encountered and entrapped a free ion of one or the other sign, as was evidenced through its abrupt changes in velocity. The more ionized the gas, the more frequent the captures.

By this process free gaseous ions of either sign have been captured at will, either singly or in multiples, and their magnitude has been so carefully measured, under conditions so free from assumptions, that the size of the electrical atom, the smallest quantity of electricity now attainable, is known probably to within one part in 500 of its actual value.

Numerically this value is the absolute electrostatic unit multiplied by 4.891×10^{-10}, a quantity incomprehensibly small. To illustrate its excessive minuteness, let us suppose one hun-

dred millions of people should begin to collect and count these atoms of electricity, just as Professor Millikan has collected and counted them, only at the extraordinary rate of 100 every minute, and let them keep steadily at it until they had enough to generate by electrolysis sufficient hydrogen to fill a child's toy balloon of some eight inches diameter. Certainly this would not be enough electricity to consider in any commercial transaction, and yet it would take the above hundred million hustlers geological ages—in fact something like four millions of years—to collect it by the process described. Surely, then, the electric ion is small beyond comprehension, and its definite isolation and exact measurement stands forth as one of the cleverest, as it is also one of the most important, achievements of modern physics.

THE EVOLUTION OF THE STARRY HEAVENS.

T. J. J. SEE

Continued from page 547.

IX. The Capture of the Moon by the Earth.

The case of the terrestrial moon is of special interest, because it is relatively by far the largest of all our satellites, and was formerly supposed by Lord Kelvin and Sir George Darwin to have had an exceptional origin. But it was shown by me in 1909 (A.N. 4343) that the moon was formed like the other satellites, and is in fact a planet which the earth captured from space, just as the other satellites were captured by their several planets. We shall not here go into the details of the moon's origin, beyond pointing out the reasons why a terrestrial origin for the moon is impossible. (1) The rupture of the earth's figure of equilibrium, which Darwin assumed to account for the origin of the moon, postulates a primitive rotation in less than three hours, or nine times faster than at present. From the causes which produce planetary rotations, as set forth above, we know that no such rapid rotation could have existed in the case of the earth. (2) Even if such rapid rotation had existed, the matter detached from the earth would have taken the form of a swarm of small bodies, and these meteorites never could have united into one mass, as now observed in our actual

moon. (3) The satellites of the other planets are recognized to be captured bodies, and the same process naturally will have operated in giving the earth a satellite, even if it is of exceptionally large mass. It should be especially noted that the large mass presents no difficulty to the Capture Theory. The anomaly lies rather in the small size of the earth, since several of the satellites of Jupiter and Saturn are fully as large as the Moon, while those of Uranus and Neptune are not enormously smaller. (4) In Darwin's celebrated graphical method for tracing the moon back to the earth, it is found to be impossible to bring the two globes close together, because at nearest approach a space of over 4000 miles intervenes between the surfaces, which cannot be bridged over. This contradiction to the terrestrial theory indicates that it is vitiated by an error, and must be unconditionally given up.

For these four weighty reasons we conclude that our moon can be nothing else than a planet which came to us from the heavenly spaces. It follows also that the earth always did rotate in about the same time as at present, and has never suffered retardation from about three hours as Darwin inferred. This simplifies very considerably many problems of Geology, and brings the Cosmogony of the earth and moon into harmony with that found in the rest of the solar system, and in the sidereal universe.

X. The Origin of the Lunar Craters and Maria.

Ever since Galileo's discovery of the mountains on the moon, it has been a problem for astronomers to explain the craters and other phenomena on the lunar surface. Notwithstanding the fact that the lunar craters are totally different from those on the earth it has been believed until very recently that they had a volcanic origin. It turns out, however, that the lunar craters are due to impact of smaller bodies against the lunar surface; and this explains the sunken character of the craters, which are all below the normal level of the lunar surface; the small volume of the walls in comparison with that of the crater basins; the steepness of the inner wall, while the outer one has a more gradual slope; the central peaks which are residues of the satellites that produced the craters; the superposition of one crater over another, and many other phenomena which show that impact, and not volcanic action, has produced the mountains on the surface of the moon. In the same way it is shown that the *Maria* are due to conflagrations

which have melted down to a dead level considerable areas of the lunar surface, only the more prominent walls here and there surviving as "ghost craters."

It is a very remarkable fact that can scarcely escape the notice of the sagacious historian of the future that prior to my work on Earthquakes and Mountain Formation (Proc. Am. Philos. Soc., Philadelphia, 1906-8), terrestrial mountains were erroneously explained by the secular cooling and contraction of the earth, whereas they are really formed by the leakage of the oceans and the expulsion of lava under the land, and the mountain ridges therefore run as great walls along the border of the ocean, as in the typical case of the Andes in South America. The current explanation of terrestrial mountain formation was thus entirely erroneous. The new theory that our mountains are formed by the sea has, however, already been very generally accepted. On the other hand, the lunar craters were supposed to be of volcanic origin, whereas they really are due to impact. Thus, wonderful as it may seem, the causes assigned in both cases were erroneous!

Besides the evidence of general character above cited the Theory as to the origin of the lunar craters by impact now rests on an absolute proof of mathematical kind as follows. It is shown by the researches of Lehman-Filhé's (A.N. 3479-80) and Strömgren (A.N. 3897) that increase of the central mass of the planet by the downfall of cosmical dust will decrease the mean distance of the satellite, but not the eccentricity of its orbit. It is shown in my *Researches*, Vol. II, 1910, that the eccentricity can be diminished only by the action of a resisting medium such as operated in the capture of the satellites. As the eccentricities of the satellite orbits usually are evanescent, showing that they have been destroyed by the action of a resisting medium, we should expect the moon's surface to bear witness to this process of cosmical bombardment, by which the orbits of the satellites have been rounded up. Thus indentations analogous to the lunar craters ought to exist, and as they are all of one type, their origin must be assigned to the impact of smaller satellites against the lunar surface. Our proof of the origin of the lunar craters is therefore essentially an absolute proof which admits of no dispute.

If it be asked why indentations similar to the lunar craters were not produced on the earth, our answer is that such terrestrial craters due to impact did exist before Geological History began, but they have since been quite obliterated by the effects

of the oceans and atmosphere, while modern terrestrial mountains of a totally different type have since been developed along the borders of our seas by the leakage of the oceans. These manifold errors afford us an impressive warning as to the worthlessness of traditional opinion, because so much of our reasoning in Physical Science heretofore has been based on false premises.

Finally it may be remarked that the satellites of Jupiter and Saturn are variable, as if covered by Maria like our own moon, so that the conflagrations which melted areas and produced Maria on our satellite have also occurred elsewhere, in accordance with the requirements of this simple theory.

XI. Original Extent of the Solar System and the Existence of Planets beyond Neptune.

Babinet's Criterion shows beyond doubt that the nuclei of the planets were formed at a great distance from the sun and have since had their orbits decreased in size, largely by the increase of the sun's mass, and rounded up into almost perfect circles, by the action of a resisting medium. As the planets were not thrown off from the sun, this is the only possible way in which they can have been set revolving in such singularly circular orbits. Moreover since it is proved in my *Researches*, Vol. II, and confirmed by the investigations of Strömgren, that the comets are surviving wisps of nebulosity coming to us from the outer shell of our ancient nebula, there is thus developed an independent line of argument showing that the solar nebula was originally of vast extent with a radius of from 10,000 to 50,000 radii of of the earth's orbit.

The proof found in Babinet's Criterion that the nuclei of the planets originated at a great distance from the sun and have since approached the center is thus confirmed by the elliptical theory of comet orbits; and thus a connection is established between the planets now near the sun and the comets still receding to great distances. In fact the planets were built up in the nebula by the gathering in of cosmical dust, such as we observe in meteor showers raining down on us from disintegrated comets; and thus all the matter now in the planets was once in the solar nebula in the form of comets. By the destruction of countless comets, the planets have been built up to their present dimensions, while at the same time they have neared the sun and been made to revolve in orbits which are

so nearly circular that the Greek philosophers believed, that the Deity had chosen the circle for the paths of the planets, because the ancient geometers regarded the circle as a perfect figure.

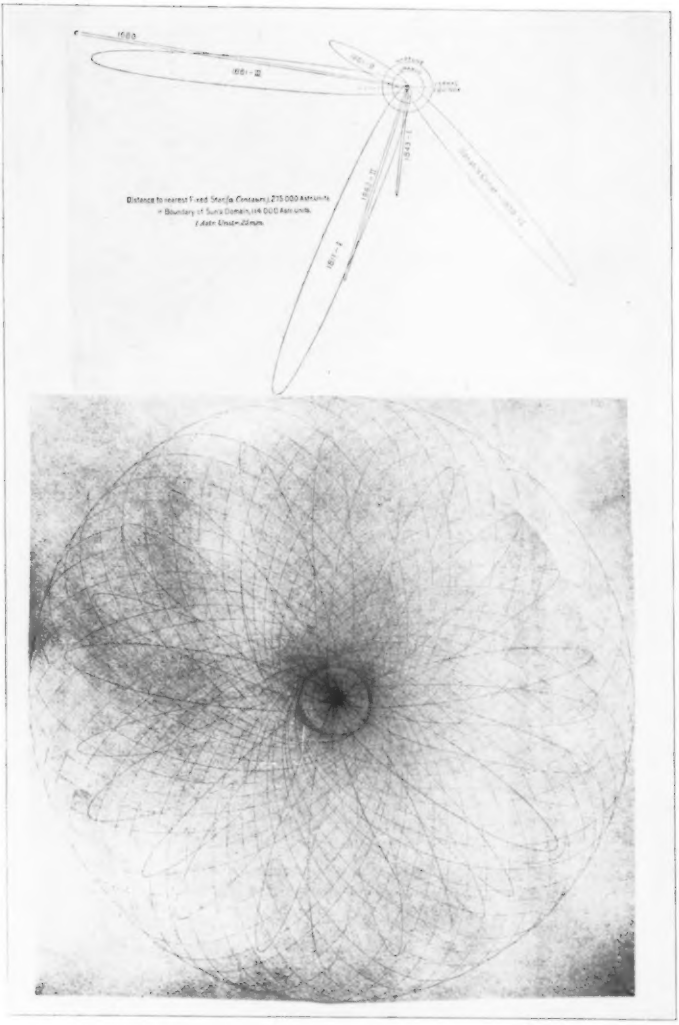
From these considerations it is evident that our planetary system extends much beyond Neptune, and several of the unseen planets revolving in this remote region of space may yet be discovered by observation. The orbital motion, however, will be very slow, and if the search is attempted by photography the exposures will have to be long and perhaps extended to successive days. Neptune's orbit is so round that we can no more think of our system terminating at this limit than we can imagine the satellites of Jupiter confined within the narrow limits of the old satellites discovered by Galileo.

XII. Nature of our System of Comets—Elliptical Orbits Predicted by Newton—Researches of Strömgren.

We have already alluded to the conclusion reached by the writer in 1909 that the orbits of all comets are elliptical, because they are the residue of the ancient nebula which formed our system and thus continue to come to us from the vast outer shell which still survives after the interior of the nebula has been destroyed in forming the central sun and planetary system. By the researches of Strömgren this is now definitely proved to be the true origin of our system of comets.

Historically the problem of the significance of the comets presented great difficulty. In 1687 Newton remarked in the *Principia* that the comets revolve in very elongated orbits, which are really ellipses, but so eccentric as to resemble parabolas in the region near the sun; and are diffused indifferently over the celestial sphere, so that they are not confined to the Zodiac, like the planets. He adds that while the law of gravitation will account for the motions of these bodies, it will not explain how they came to be started in such widely dispersed orbits. The formation of our system from a nebula made up of elements expelled from the stars of the Milky Way and thus gathered together from all directions in space is the only possible explanation of the system of comets. It thus points to the general operation of Repulsive Forces in Nature, and constitutes an impressive illustration of the formation of nebulae gathered from a system right at hand.

PLATE XXIII.


1680
1882 - II
1843 - I
1881 - II
1881 - I
Distance to nearest Fixed Stellar Concourse 215,000 Astr.Units
= Boundary of Sun's Domain 144,000 Astr.units.
1 Astr. Unit = 93mln.

ILLUSTRATIONS OF THE NEW THEORY OF COMETS DEVELOPED BY T. J. J. SEE.

The lower figure illustrates the vast system of small bodies circulating about the Sun and constituting the outer shell of the primordial nebula. The upper figure from Lowell's "Solar System," shows the orbits of a few actual comets which have appeared in the short interval since Newton's famous comet of 1680.

This theory of the origin of our system of comets has been confirmed by the researches of Leuschner (1906) and Fayet (1906) and more especially of Strömgren (*Vierteljahrsschrift*, October, 1910), who subjected the supposed hyperbolic comets to a critical test, and found every one of them to be elliptic; so that we have to abandon the view long held that some of these bodies move in parabolas and hyperbolas. After two centuries of wandering in the wilderness we thus return to Newton's view of 1687. And the reason for the elliptical orbits of comets is to be found in the nature of the system of comets, wisps of nebulosity coming from the outer shell, as the surviving residue of the ancient nebula which formed our solar system.

XIII. Universality of Repulsive Forces in Nature Established by Herschel's Argument Regarding the Operation of Central Powers in the Cluster and Nebulæ.

In the Philosophical Transactions of the Royal Society for 1789, 1811, and 1814 Sir William Herschel has developed a powerful and celebrated argument for the operation of central powers in the formation of star clusters and nebulæ. The star clusters tend to globular figures, and increase in density toward their centres; and the same tendency is shown to operate in the nebulae, many of which seem to be made up of concentric spherical shells of uniform brightness, but accumulating towards the center in such a way as to show a gradual increase of density with maximum in the nucleus, which often is occupied by a nebulous star. There are thousands of these objects, all following the same law, and on the uniformity of the tendency Herschel founds his irresistable argument for the operation of central powers in shaping and moulding the figures of sidereal systems.

Herschel's discussion is so convincing that we need not dwell on it beyond adding that if now we exactly *reverse his argument* we obtain at once a most comprehensive proof of the universal operation of repulsive forces in Nature. For if central powers produce the observed symmetrical condensations, it is obvious that the matter now condensed was formerly diffused somewhat equably about these centers, and could have acquired this arrangement in space only by accumulation from all directions: and therefore at an earlier period the matter was expelled from stars lying in all directions in the general stratum

of the Milky Way. Accordingly we thus obtain a most satisfactory proof of the operations of Repulsive Forces throughout Nature. The familiar proofs of repulsive forces supplied by the Solar Corona and by the tails of comets pointing from the sun, are thus supported by others drawn from the system of comets about our sun and from the star clusters and nebulae in every part of the sidereal heavens.

XIV. Arrangement of the Nebulæ in Canopies on Either Side of the Milky Way due to the Action of Repulsive Forces.

If repulsive forces are everywhere at work expelling dust from the stars for the formation of nebulæ, it is evident that as it is repelled by the stars it will tend to gather especially in vacant regions or spaces remote from the stars, and should accumulate with maximum density near the poles of the Milky Way. Thus have arisen the great canopies of nebulae on either side of the Galaxy. As the dust now forming into nebulæ slowly developes into stars, they drift back into the central starry stratum of the Milky Way, while other new nebulæ take their places: so that the *arrangement of contrariety*, with nebulæ on either side of the starry stratum, is maintained by a process of slow circulation. The observed arrangment of the nebula and stars in the sidereal universe is thus the outcome of the grouping of the stars in one great stratum, which may itself be the effect of the mutual attractions of the whole mass and of repulsive forces operating over vast time.

For over two centuries after the establishment of the law of universal gravitation by Newton in 1687, philosophers took account of attraction only, and ignored the effects of Repulsive Forces, so that the Natural Philosophy of the heavens was essentially incomplete, being but half developed. In more recent times account has been taken of Repulsive Forces and their paramount part in dispersing matter for the formation of sidereal systems, and the result is the full treatment of the two great tendencies in nature, with a more symmetrical development of the grand Science of Natural Philosphy.

XV. The Uniformity in the Distribution of the Chemical Elements Discovered by Huggins in 1864 also Implies the Operation of Repulsive Forces in Nature.

The beautiful discovery of Sir William Huggins, in 1864, that the chemical elements are essentially the same wherever a star

PLATE XXIV.

ISOGRAPHIC PROJECTION OF THE NORTHERN CELESTIAL HEMISPHERE.

The nebulæ are represented by dots, the clusters by crosses.

twinkles, may be said also to point to repulsive forces in nature. For if these were not incessantly at work, to keep the elements well stirred, by a process of mixing, it is probable that transmutations going on in certain places might develop at length great inequalities in the distribution of the elements, and the universe would not present the aspect of essential uniformity so clearly disclosed by observation. These results reveal to us some of the greatest laws of nature, and give us the true cause for the wonderful order found to pervade the starry heavens.

When we consider the hazy, dust-like aspect of the nebulæ it is strange that we should not earlier have read the riddle of these remarkable objects as produced by the gathering together of dispersed dust; for the existence of these cosmical clouds in the universe is as clear an indication that matter is dispersed from the stars by the action of repulsive forces as that aqueous clouds in our atmosphere are of the renewal of terrestrial evaporation. Any philosophic observer studying the nebulae through the telescope ought to have been able to recognize that these hazy cloud-like masses are essentially the evaporation-products of the stars, and that they must be incessantly renewed by the repulsive forces at work from these centers of condensation and radiation.

But false ideas of Cosmogony were everywhere prevalent, and instead of looking upon the nebulæ as renewed by the expulsion of dust from the stars, the current view was that the nebulae represented world stuff not yet used up since the Creation. Now in the arguments of the great Herschel, before cited, he shows that some of the sidereal systems have been millions of ages in forming, and as others have been of very different duration, it is possible to prove mathematically that the formation of all parts of the Universe did not begin at any one epoch, however remote, but is a process of constant renewal, under the cyclic process here described, the condensation of the nebulae forming stars and planetary systems and the expulsion of dust from the stars forming the nebulae.

The philosophical difficulty now overcome by the introduction of Repulsive Forces for scattering the dust from the stars and thus producing nebulae, and finally setting the bodies, into which the nebulae condense, in orbital motion, as if by the action of projectile forces, is one which has been recognized since the time of Anaxagoras (500-427 B.C.) He taught that the sun, moon, and stars had been torn away from the (sup-

posed) common center of the earth by the violence of the Cosmic Revolution, just as Kant and Laplace long afterwards supposed the planets to have been thrown off by the rotation of the solar nebula. Anaxagoras' difficulty of accounting for the tangential or projectile forces which set the heavenly bodies in motion is stated in the notable work on *Greek Thinkers*, by Professor Theodore Gomperz of the University of Vienna as follows:

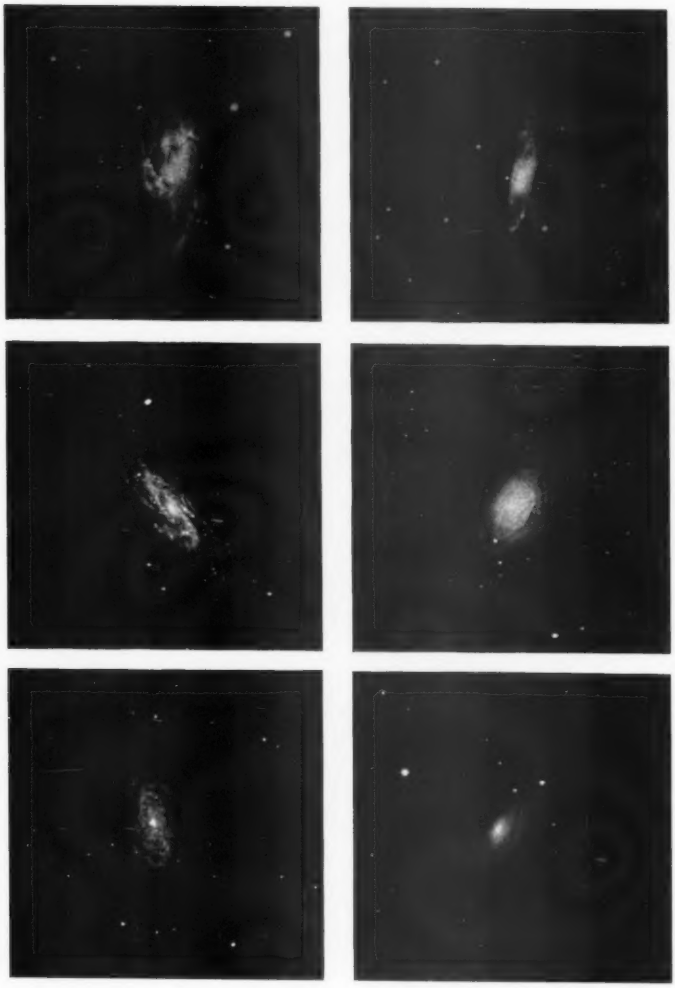
"There was only a single point in his theory of the formation of the firmament and the universe in which he deserted his mechanical and physical principles to assume an outside intervention. That first shock which set in motion the process of the Universe that had hitherto been in repose reminds us in a most striking fashion of the first impulse which the Deity is supposed by some modern astronomers to have given to the stars. Or rather it would be more correct to say that both ideas are practically identical. They were intended to fill up the same lacuna in our knowledge: they spring from the same desire to introduce in the mechanism of heaven a second force of unknown origin to take its place by the side of gravity." (*Greek Thinkers*, p. 217, translated by Magnus, 1901).

The explanation of *projectile forces* (such as those which set the planets revolving) now adopted, rests on the original dispersion of dust by the stars, and its inevitable collection into a nebula of unsymmetrical figure, which gradually settles and coils up, thus producing a whirling vortex about the center of the nebula, which becomes the sun, while the surviving planets circulating about it have their orbits reduced in size and rounded up into almost perfect circles by the action of the resisting medium. This is a vast improvement in our theories of the mechanics of the heavens, and as it follows directly from well established laws of motion, the traditional difficulty in the mechanical theory of the Universe completely disappears, and we see that the revolutions of the stars is a necessary consequence and a proof of the coöperation of Attractive and Repulsive Forces in Nature.

XVI. Spiral, Annular, Elliptical, Planetary and Irregular Nebulæ.

As nebulae arise from the collection together of particles of dust expelled from the stars, it naturally follows that the clouds thus developed will seldom be of perfectly regular figure,

PLATE XXV.



SPIRAL NEBULÆ PHOTOGRAPHED AT LICK OBSERVATORY.

H. I. 205, Ursæ Majoris
M 81, Ursæ Majoris
M 65, Leonis
H. I. 56-57 Leonis
H. I. 199, Ursæ Majoris
M 66, Leonis

but will often consist of two or more streams settling down and coiling up under the effects of their mutual gravitation. The settling of a stream of unsymmetrical figure towards its center of gravity thus produces a *spiral nebulæ*. In rare cases the streams may coil about in such a way as to produce an *annular* or *ring nebula like that in Lyra*. *Ring nebulæ* are therefore special cases of the more general type of *spiral nebulæ*. If the whirlpool is of somewhat even density, and viewed obliquely, it appears to be an *elliptical nebula*. When the elements come together somewhat symmetrically from all directions, and the density is somewhat uniform, we have a *planetary nebula*—a type which seems to be quite numerous. Most of the nebulæ, however, are of irregular figure, as ought naturally to happen from the way they are formed. In time they tend to settle down and assume more symmetrical form, but the process is excessively slow, owing to the feebleness of the attractive forces, and the rarity of the mass of cosmical dust, which usually allows the light of stars to pass through it, even when thousands of times the diameter of the solar system.

For a long time after the age of Herschel and Laplace it was usually assumed that the nebulae are *figures of equilibrium* maintained by high temperature and hydrostatic pressure, but of late years these views have been quite abandoned. The nebula are much too rare for the exertion of any hydrostatic pressure. This is proved from actual calculation in the solar system, by the fact that if the sun be expanded to Neptune's orbit, as held in the abandoned theory of Laplace, the density of the resulting nebula is 260 million times less than that of atmospheric air at sea level, or thousands of times less than that of the most perfect vacuum attainable.

A planetary nebula is therefore analagous to the infinite system of comets revolving in all directions about the sun, except that the comets are dense enough to render the whole nebula faintly visible, which probably is not true of *our system of comets* as seen from the other fixed stars. The vast extent and incredible rarity of our system of comets and meteoric trains is the best known illustration of what the average nebula really is.

Some nebulae contain certain self luminous gases, probably shining at very low temperature by luminescence or electric excitation, but most of the elements are non-luminous and give no spectral indications of their presence.

XVII. The Principal Cause of Variable Stars to be Sought in the Action of a Resisting Medium.

It is shown in my *Researches on the Evolution of the Stellar Systems*, Vol. II, 1910, that, although quite unseen, planetary systems really exist about the fixed stars which appear to be single under the most refined observations of our greatest telescopes. Our instruments reveal to us chiefly the bright companions at some distance (visual double stars), or massive companions revolving rapidly and in such close proximity as to become visible only by the periodic shift of the spectral lines (spectroscopic binary stars). In both classes of these objects the masses must be considerable, while the planets attending the fixed stars revolve quite unseen and forever beyond the reach of our most powerful instruments.

We know that planets attend the fixed stars for two reasons: (1) They attend our sun, which is definitely known to have developed from a nebula; (2) The mode of formation which was operative when the planets began as small nuclei in the distance and neared the center of the system under the attraction of gravitation, will necessarily have operated in the same way about the other stars, which arose from nebulae under the very same laws. Therefore the fixed stars generally have systems of planets, asteroids, satellites, and comets; and the double stars are simply those systems in which the smaller bodies have been so united as to produce large companions.

Now as all the stars have companions, and the resisting medium exists everywhere, though with varying density, it follows that those companions which plunge through considerable resistance at perihelion will experience a variation in brightness. The blazing up of the light will be comparatively rapid, the fall in brightness more gradual, depending on the slower process of cooling. These are the variable stars, of which more than a thousand are known.

Some clusters are quite filled with variable stars, and it is observed that their periods are very constant. This shows that these clusters are still supplied with ample nebulosity, and that variation of such great regularity can depend on nothing but orbital motion for its regulating cause. Where the variation is irregular, one should suspect the presence of several disturbing bodies, the compound effects of which do not give regular periodicity. In other cases there are phenomena of eclipses to be dealt with, as in the Algol and Beta Lyrae variables, but we need not dwell on these details.

The important thing for us to observe is that the great cause which has rounded up the orbits of our planets, enabled the planets to capture their satellites, and given rise to the lunar craters, by the destruction of millions of small bodies, is operative throughout the universe; and it is therefore no wonder that many of the stars are variable.

XVIII. New Stars due to Collisions with Attendant Bodies.

As all the fixed stars are attended by systems of planets and comets, it will inevitably happen that collisions of disastrous character between some of these bodies and their central suns will occasionally occur.* My investigation of this question proves that the Novae follow the Milky Way in just the proportion that should occur if the outbursts depend simply on the thickness of the stars on the back ground of the sky, so that wherever the stars are numerous there the Novae will appear.

It was formerly supposed by some that the stars actually come into collision with one another; but it is now realized that such disasters are too rare to become noticeable, whereas collisions with attendant planets or comets within the system must be infinitely more frequent. Above all, as the Novae are of short duration, this fact points to conflagrations such as might follow from the collision of a small mass, but not of one sun with another. Accordingly it has come to be accepted that the new stars are due to collisions with minor masses of the type of planets or very large comets.

The theory that a comet might fall into a star which had wasted in splendor was held by Newton, and thus our modern view is merely an extension of that put forth by the immortal author of the *Principia* in 1687.

XIX. Connection Established Between all Classes of Heavenly Bodies.

The most significant result of the New Science of Cosmogony as now developed is that these laws unite all the different classes of the heavenly bodies into one continuous and un-

* In this way probably arise the so-called *Stellar Nebulæ*, which are correctly distinguished from the *planetary nebulæ*. The former follow the Milky like the *Novæ*, and undoubtedly these two classes of objects are connected, though this apparently has not been suspected heretofore.

broken whole. Every star is a sun, attended by an infinite system of comets, and by companions, whether the system has the form of a double star or the more general type of a planetary system made up of numerous small bodies. Whenever a system has a dominant body like Jupiter, it has also a system of asteroids gathered within its orbit, and a group of short period comets, such as our own Jupiter has captured. The comets are destroyed, and the dust of their disintegration serves to build up the masses of the planets.

In the transition of the asteroids over Jupiter's orbit, some are captured and become satellites, which usually have a direct revolution, but a lesser number may move retrograde, as actually observed in the solar system. The collisions of captured particles with the planets give these globes a direct rotation on their axes, and establish obliquities like those observed in the planets revolving about our sun. The meteors, comets, asteroids, satellites and smaller planets are consumed in building up the larger bodies of the system. If a large companion revolves in an eccentric orbit, most of the planetary bodies may be swallowed up in one of the two large masses and thus lead to the development of a double star. Should the stars be far apart there may arise a closer companion giving a triple or quadruple star, or one of the components of a double star may become a spectroscopic binary. When a nebula of vast extent is formed and develops by condensation at many centers we have a cluster, with companions attending the individual stars, and by revolving in the nebular resisting medium giving us *cluster variables*, often with wonderful regularity of period.

Collisions of large comets or planets with suns which have wasted in splendor supply new or temporary stars, which blaze forth wherever the stars are crowded on the background of the sky, and therefore principally along the course of the Milky Way. The dust expelled from the stars to form nebulae may take any of the observed forms, and thus we have *spiral, annular, elliptical, planetary* and *irregular nebulae.* Astronomers now recognize the following classes of Cosmical bodies: 1. single stars: 2. double stars, including both visual and spectroscopic binaries; 3. multiple stars; 4. clusters of stars; 5. star-clouds in the Milky Way; 6. the Milky Way itself, as a clustering stream of smaller systems traversing the circuit of the heavens and here and there culminating in a perfect blaze from the intensity of the accumulated starlight; 7. variable stars;

8. temporary stars; 9. planetary systems; 10. systems of satellites; 11. systems of asteroids; 12. systems of comets; 13. spiral nebulae; 14. annular nebulae; 15. elliptical nebulae; 16. planetary nebulae; 17. irregular nebulae; 18. diffuse nebulosity, often covering whole constellations; 19. canopies of nebulae accumulating with maximum density near the poles of the Milky Way; 20. two or more streams among the stars, indicating that the observed order of the universe is slowly changing with the flight of ages.

It is obvious that a science of Cosmogony which is founded on a true basis should connect these different classes of bodies one with another, and thus establish an unbroken continuity in the observed order of nature.

In the new edition of the *Encyclopedia Britannica*, under the article *Stars*, it is pointed out by Mr. A. S. Eddington of the Royal Observatory, Greenwich, that a fundamental contradiction arises in our conceptions of Cosmical Evolution when, on the one hand, we try to pass from systems of binary stars and planets, supposed to be thrown off from the central nebula by the fluid fission process of Poincaré and Darwin to the star clusters, on the other, which are supposed to be due to the aggregation of matter towards centers, as imagined by Herschel. If Mr. Eddington had read my papers of 1909 carefully, and above all the second volume of my *Researches*, 1910, he would have seen that this long standing contradiction is now permanently removed, because I have proved that the uniform law of nature is one of aggregation of matter towards the large centers of attraction, while the only throwing off that ever takes place is that of small particles expelled by the action of Repulsive Forces. Mr. Eddington's article doubtless was prepared several years ago, but the failure to bring it up to date in this and many other cases shows that the *Britannica* is antiquated before it leaves the press, and it is not remarkable therefore that it has so largely disappointed the scientific world.

From the foregoing theory it thus appears that we have a simple and consistent explanation of all classes of the heavenly bodies in their mutual relationship and distribution in space. The harmony and order thus introduced into apparently confused and extremely varied phenomena is the best proof that the laws now recognized are the true laws of Nature.

XX. Philosophical Significance of Plato's Celebrated Saying that the Deity always Geometrizes.

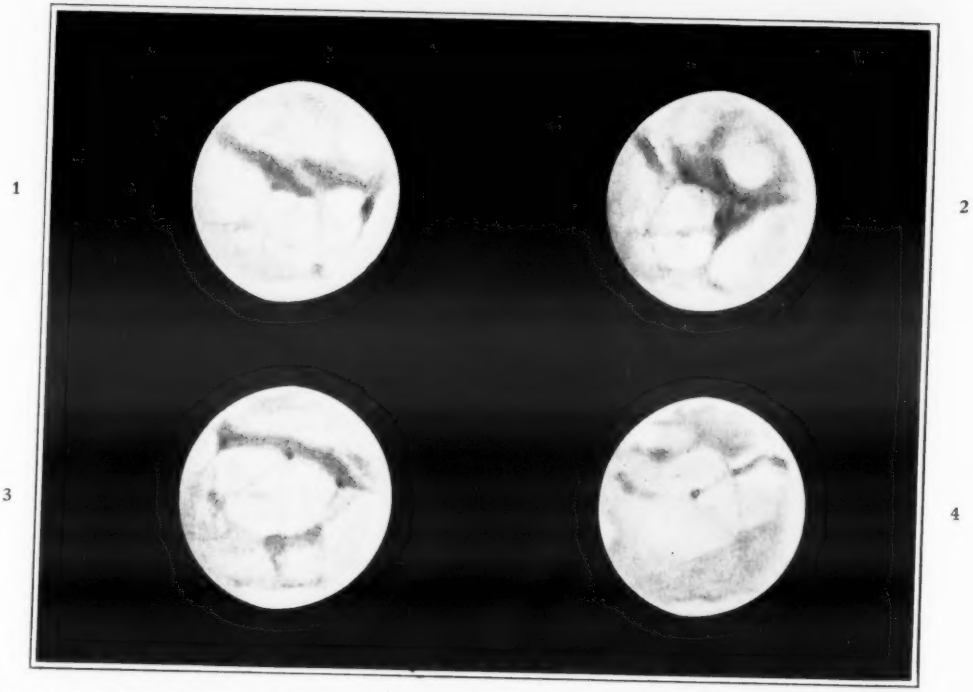
One of the most beautiful of these laws, as disclosed by the New Science of Cosmogony, appeals especially to the geometer. And as it has left a profound impress upon the Geometry of the Heavens, we may conclude these remarks by a brief explanation of it. We have seen that the nebula are formed by the gathering together of fine dust expelled from the stars, and that it eventually condenses into larger bodies. The unsymmetrical figure of a nebula often causes it to settle, under its own gravitation, and develop into a spiral resembling the spiral of Archimedes. The sun of the system develops at the center, while planets are formed in the distance and made to approach the sun in orbits becoming smaller and smaller and rounder and rounder, owing to the secular effects of the nebular resisting medium. And the final outcome is a planetary system of the beauty and order found about our sun, the planets being attended by captured satellites and endowed with axial rotation and small obliquity, often surrounded by atmospheres and oceans, with all the conditions favorable for habitability.

This development represents one of the greatest and most general laws of Nature. Now if drawing ellipses and slowly transforming them into circles for the orbits of planets, and thus establishing orderly systems out of the chaos of a spiral nebula may be considered geometrizing, then Plato certainly was right when he declared that the Deity always geometrizes —ὁ θέος ἀει γεωμέτρει.

A sublimer truth than this probably never will be disclosed to mortals. When we behold the starry heavens on a cloudless night we may well recall the Geometrizing of the Deity which is always going on for establishing the beauty and order of the Cosmos.

U. S. Naval Observatory,
Mare Island, California,
August 7, 1911.

PLATE XXVI.



MARS AS SHOWN WITH AN ELEVEN INCH REFLECTOR. DRAWN BY LATIMER J. WILSON.
POPULAR ASTRONOMY, No. 190.

MARS AS SEEN WITH AN 11-INCH REFLECTOR.

LATIMER J. WILSON.

Certain parts of the disc of Mars seem to be subject to the formation of very conspicuous and brilliant white spots during the present apparition of the planet. On October 12, at 10h 50m the region preceding the Syrtis Major was unusually light. On October 14, at 12h 5m, C.S.T., it was intensely brilliant, and numerous light spots were seen in the area following Hesperia.

Several instances of extraordinary white spots are shown in the accompanying drawings.

(1) λ 235.5° = center, Oct. 20, 12h 0m, Libya and Hellas exceedingly bright. White on the northern cap in λ260° extends nearly to +30°.

(2) λ 275.5° = center, Oct. 22, 15h 4m, small white spot at λ 280°, north lat. 10° to + 30°.

(3) λ 205° = center, Oct. 26, 12h 30m, white borders the southern part of the dark strip from the Primus Lucus to the Lucus Lucrinus.

(4) λ 110° = center, Nov. 2, 10h 52m, a rather large light spot was central on λ 110°, north lat. 13°. A conspicuous white spot was on the terminator at about 15°, north lat. The region from the Solis Lacus to the limb of the planet, south of Nectar became intensely brilliant as it approached the limb.

During the opposition of 1909 such very bright spots in tropical and semi-tropical regions were not often recorded here, and as far as my observations are concerned their frequent formation at present is unusual and interesting.

Nashville, Tenn. 803 Shelby Ave.

THE PERSEIDS 1911.

R. M. DOLE.

The Perseids this year were not as numerous as in 1910, which may have been due somewhat to the strong moonlight. August 10 was hazy with a strong moon, and not a Perseid was seen in an hours watch 10-11. August 11 was a fairly clear night, with a brilliant moon. From 11.15 to 3.43, 135 Perseids were counted and 17 from other radiants. August

12 was clear until 12.25 when 35 were counted between 8:30 and 12.25. No. 86 was one of the brightest the writer has ever seen, distinctly rivalling a quarter moon in light.

		Perseids	Others	
July 27		1		
Aug. 11	11.15 — 11.30	13	1	
	11.30 — 12.00	4		
	12.00 — 12.30	9		
	12.30 — 1.00	15	7	
	1.00 — 1.30	14		
	1.30 — 2.00	15		
	2.00 — 2.30	17	6	
	2.30 — 3.00	20		
	3.00 — 3.30	19	3	
	3.30 — 3.43	9		Total 136
Aug. 12	8.30 — 11.30	17	17	
	12.00 — 12.25	18		35
				171

Of 171, 32 left distinct trails, green or white; four were a distinct blue, nine were red or orange and the rest white. Of 117 recorded the magnitudes were as follows:

−4	−2	−1	0	1	2	3	4	5	6
1	3	3	15	21	23	28	15	3	6

Because of the strong moonlight, there were few faint ones seen. The Aquarids on May 5 gave seven between 2.00 and

PERSEIDS AUGUST 11, 1911.

3.00, and 10 on May 6 between 2.30 and daylight. The Lyrids on April 20 were so few, only three in one hour, that no watch was kept. The shower from Leo in March gave three extraordinarily bright meteors, two being seen through light clouds and attracting much attention. The Aquarids in July were not seen because of persistently poor weather.

Ogunquit, Maine.

A MODERN LOOK AT THE UNIVERSE.*

HENRY OLERICH.

Mr. Olerich is not an astronomer but a popular writer and lecturer. In this article, which will be continued through the January and February numbers of Popular Astronomy, he gives a very clearly written and well illustrated account of the Nebular Hypothesis of Laplace. While this hypothesis has never been accepted by astronomers as a proven theory and today must be considerably modified to meet the serious objections which are raised against it, yet we think our readers will find the clear statement here given of great interest, especially in connection with the preceding articles by Dr. See. [*Ed.*]

Emerson says:

"I am owner of the sphere,
Of the Seven Stars and the Solar Year,
Of Caesar's hand and Plato's brain,
Of Lord Christ's heart and Shakespeare's strain."

Let us now endeavor to reach out as far as we can after Emerson's ideal, so profoundly expressed in this brief poem, so that we may be all the more able to take the most comprehensive and truthful view of the Universe that Science has so far been able to reveal to us.

The Science which investigates the Universe as a whole is called *Cosmogony*. Cosmogony is, therefore, the broadest and most comprehensive of all sciences; for it includes *all* phenomena, all other sciences, and the yet *unknown* as well as the known realms. Hence it is plainly evident that on such a limitless subject, there can be but few details. Only a few of its more important general laws and principles can be briefly investigated in one short discourse.

Solar System.

First let us take a brief glance at the *present* Form and Functions of our Solar System with which we are all quite familiar, and then try to explain how it came to be as we now find it.

* An address delivered in the auditorium of the Omaha Public Library June 20, 1911, the Centennial Anniversary of the popular birth of the Nebular Hypothesis.

As we all understand, our Earth is one of a little group of heavenly bodies known as the solar system. The principal members composing our Solar System are: the Sun as the attractive center of our system; the eight primary planets—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune; twenty-six known Moons or satellites, of which the earth has one, Mars two, Jupiter eight, Saturn ten and an unbroken ring, Uranus four, and Neptune one; over seven hundred asteroids or minor planets; and an unknown number of comets—some astronomers estimate the number to be as many as 7,500,000.

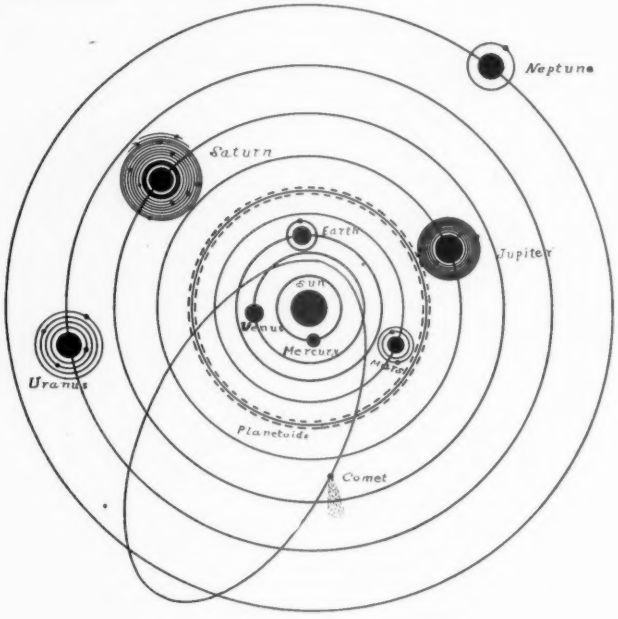
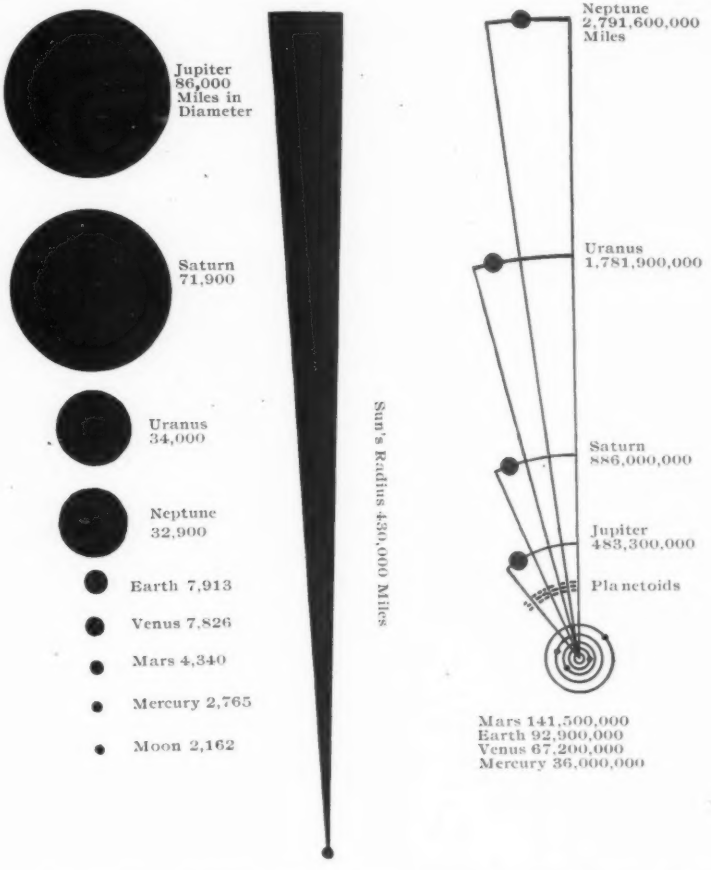


FIGURE 1. PRESENT SOLAR SYSTEM.

One Sun. Eight Primary Planets. Over 700 Asteroids or Minor Planets. Twenty-six Moons or Satellites. An unknown number of comets, and a few unimportant minor bodies constitute the *present* Solar System so far evolved. Relative size and distance not proportional.

All the members of the solar system are also in rapid motion of some kind. For instance, the sun now makes a complete rotation on his axis once every twenty-five days and five hours. All the other members revolve "around" the sun in

nearly the same plane from west to east, and almost parallel with the sun's equator; and the nearer to the sun the faster is their orbital velocity. The velocity of Neptune, the outermost and therefore the slowest of the planets is about three miles per second, that of the earth nineteen miles per second, and that of Mercury about thirty miles per second, which is about a hundred times faster than the velocity of a cannon ball (1600 ft. per second).



The seven hundred and more asteroids or minor planets revolve around the sun in somewhat irregular orbits located between the orbit of Mars and that of Jupiter. The host of

comets belonging to our solar system also revolve around the sun in orbits much more elliptical than those of the planets and moons, so that their velocity greatly varies as they are nearest (perihelion) or farthest (aphelion) from the sun, and the whole solar system is also speeding at the rate of about twelve miles per second toward a point in the constellation Hercules.

So far as definitely known, all the primary planets also *rotate* on their axes from west to east, or opposite to the hands of the clock. *Why* they rotate, and *why* some of them rotate so much faster than others will be explained presently. The moons also rotate on their axes, and revolve around their primaries in obedience to the same mechanical laws as the planets revolve around the sun.

The members of the solar system greatly vary in size. In round numbers, the sun is 860,000 miles in diameter, 1,300,000 times larger than our earth, and 550 times larger than the combined volume of all the planets. Jupiter is 86,000 miles in diameter; Saturn 71,000; Neptune 32,000; Uranus 34,000, the earth and Venus each about 8,000; Mars 4,000; Mercury 3,000; our moon 2,000; and Deimos, the outer little moon of Mars, which is the smallest of all the known moons and planets, is about six miles in diameter. The area of the whole surface of Deimos is therefore much less than that of many a western ranch.

As before intimated, the length of day and year also greatly vary on the different planets. Mercury is 36,000,000 miles from the sun and speeds around it in 88 days. Our earth is about 93,000,000 miles from the sun and completes a revolution in a little over 365 days. Neptune is nearly three billion miles away and requires 60,000 days or 164 of *our* years to make one revolution around the sun, which is equal to the Neptunian year.

As we all know, our earth rotates on its axis once every twenty-four hours, which causes the phenomenon of day and night. The large planets Jupiter and Saturn complete a rotation in about *ten* hours. Their day and night is therefore considerably less than half as long as ours. A day and night on our moon is 672 hours.

The *density* of the planets varies almost uniformly as we proceed from the outer to the inner members. The density of Neptune is one-fifth that of the earth, Jupiter one-fourth, and Mercury two and one-fourth times that of the earth.

Surface gravity depends on mass and radius. Our 100-pound man would weigh 2700 pounds at the surface of the sun; 265 on Jupiter; 38 pounds on Mars; and about one pound on the little moon Deimos. At the surface of the sun, the force of gravity is so great, because the sun is so massive, that the strongest earth-man could not rise, if he were lying down; and if he stood up, his feet would be so heavy that he could not move them. On the other hand, on the little moon Deimos, gravity is so feeble that he could easily hop over any sky-scraper, or leap from the pinnacle of the Eiffel Tower a thousand feet high without injury. On this little satellite, it would be easy to fly, and not much danger in falling most any distance.

Perhaps the greatest diversity exists in the *physical* conditions of its members. The sun, Jupiter, and Saturn on account of their large size, are still in a molten condition. Venus and the earth are approaching their *prime* or maximum maturity. Our moon on account of her comparatively small size has already cooled down to a dead cinder. The air and water have all been slowly absorbed by the cooled interior. Mars, which is also comparatively small, also seems to be sharing the fate of the moon. These seem to be pointers that worlds and suns are born, develop, grow old, and finally die the same as individuals and species do. Briefly stated, such is the present form, functions, and physical conditions of our solar system.

Nebular Hypothesis.

But science teaches that our solar system did not *always* have the *present* form and functions; that it slowly evolved out of *one* huge moving nebula, slowly separating by mechanical causes at long intervals into its *present* revolving and rotating members. The Nebular Hypothesis is a theory that endeavors to explain the mechanical causes that produced the gradual evolution of our solar system from a primitive nebula to its present complex form and functions.

The Nebular Hypothesis, which forms the basis of my investigations and experimental tests here, was first suggested and popularized by the eminent astronomer, Sir William Herschel, in a paper read before the Royal Society, on June 20, 1811, though the germ of it may be found in Kant's "General Natural History and theory of the Heavens," published in 1755. It

was further developed by Pierre Simon Laplace, the famous French Astronomer and mathematician, with whom it came to be specially associated.

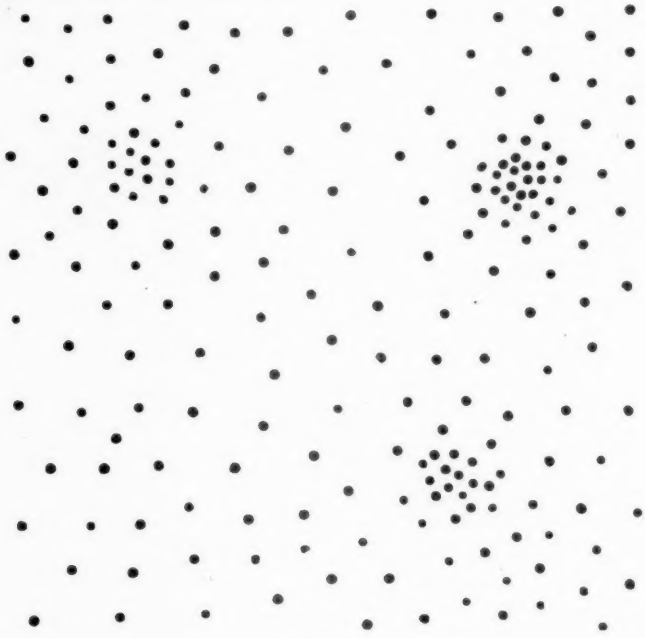


FIGURE 3.

This square represents a vast section of the Universe, hundreds of billions of miles in extent. The little dark circles represent isolated electrons still quite evenly distributed throughout that section of space. Three nuclei for Nebulae are, however, beginning to form. On account of the fierce heat, perhaps no atoms, molecules, and chemical elements and compounds are yet possible.

The Nebular Hypothesis assumes that long, long ago, perhaps hundreds of millions, or thousands of billions of years ago, all suns were either *simultaneously* or *successively* in a *nebulous* state; that the nebulous matter of which they were originally formed was widely and quite uniformly scattered throughout space, but later began to gravitate toward certain slightly denser centers. The particles or masses moving toward these centers not doing so with *equal* velocities and momentum, or in the same direction, a slight *rotation* on an axis would result in the nebulous mass; and, if by radiation of heat, the par-

tially contracted nebula or primitive sun still further contracted, his rotary velocity would have to continue to increase by reason of a mechanical law which we shall hereafter elucidate; and as soon as the rotation had increased so much that the *centrifugal force* of the *outer* equatorial border overcame that of *gravity*, a ring or belt would be shed or left behind from the equatorial region of this rapidly rotating nebulous sun.

As we shall presently see, this revolving ring, in obedience to well-known mechanical laws, must form itself into a *spherical* planet, *rotating* on its axis with ever-increasing rotary velocity; so that eventually a ring would also be shed from this large, newly-born, highly-heated, gaseous planet from which, in like manner, a *moon* or satellite was formed. As the contraction and consequent increasing rotary velocity of the sun and planets thus continued, ring after ring was, at long intervals, shed from which all the planets and moons of our solar system slowly evolved themselves to their present form and function, and this same evolution is still as ever going on. The solar system is slightly different to-day than it was yesterday, and will be different to-morrow than it is to-day.

Briefly stated, these are the fundamental doctrines advanced by the Nebular Hypothesis in respect to the gradual evolution of our solar system; and as we shall presently see, it is highly probable that every "fixed" star is an enormous central Sun rotating on its axis and evolving by the same mechanical laws a solar system similar to our own.

In the two last topics in this series of articles, the writer will enumerate some of the strongest proofs in favor of the nebular hypothesis, and will also answer the principal objections that have so far been urged against it. I will here say merely that I am in full accord with the late Professor S. Newcomb's announcement "that the Nebular Hypothesis is indicated by the general tendency of the law of nature, and that it has not been proved inconsistent with *any fact*."

Matter, Force and Motion.

Before we can successfully point out the particular mechanical causes that are instrumental in the formation and evolution of the solar system, it will be necessary to take a brief glance at the ultimate structure of matter and modes of motions; for all phenomena of *Form* and *Function* known to man are due to transmutations of matter and motion.

Science teaches that all matter is composed of exceedingly minute particles called *molecules*, and that each of these molecules is composed of two or more still smaller particles called *atoms*.

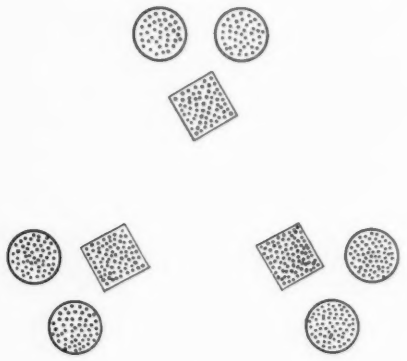


FIGURE 4.

MOLECULES, ATOMS, AND ELECTRONS.

These three groups of three circles each, represent three molecules of water, each composed of three atoms. The *square* in each molecule represents an atom of oxygen; the two *circles* in each molecule represent atoms of hydrogen, and the small dots in the squares and circles represent *numerous* electrons. The molecules, atoms, and electrons of all matter are supposed to be in constant oscillatory motion.

For example, that a molecule of water is composed of one atom of oxygen and two atoms of hydrogen; a molecule of common salt of one atom of sodium and one of chlorine, and so with all other substances whether solid, liquid, or gas; but in general, the more complex the particular substance the more atoms in a molecule. The molecule of the highly organized brain substance is made up of myriads of atoms. This theory is known as the *Atomic Theory*, and was first propounded in 1804, by John Dalton the famous English Chemist.

No one has ever seen an individual atom or molecule. Scientists estimate that the chemical atom is so infinitesimally small that it requires a group of not less than a billion to make the group barely visible under the most powerful microscope, and a thousand such groups would have to be put together in order to make it just visible to the naked eye as a mere speck floating in the sunbeam.

Until recently it was thought that the chemical atom could not be further subdivided, but the recent discoveries of Radium, X-rays, and other modern researches seem to establish the fact that each atom is composed of numerous still smaller particles called *electrons*; that an atom of hydrogen contains at least 1500 electrons, and an atom of radium not less than 300,000 electrons.

In the organic world the minuteness is even more conspicuous. The microscope reveals innumerable animalcules in a hundredth part of a drop of water. They all eat, digest, move and from all appearances of their frolics, they are endowed with sensation and ability of enjoyment. What then shall we say of the minuteness of the food they eat; of the blood that surges through their veins; of their nervous system that thrills and guides them? Their minutest organs must be composed of molecules, atoms and electrons inconceivably smaller than are the organs themselves. These few suggestions afford us at least a faint idea of the infinite minuteness of the visible universe, so that we can the better understand and appreciate the endless *transmutations* of matter, energy, and motion, whether in the microscopic body of an animalcule, a world, a solar system, a glowing star, or a telescopic nebula.

To be continued.

PLANET NOTES FOR JANUARY, 1912.

C. H. GINGRICH.

During this month the sun will move from the constellation Sagittarius into the constellation Capricornus. It will also move north about five and a half degrees.

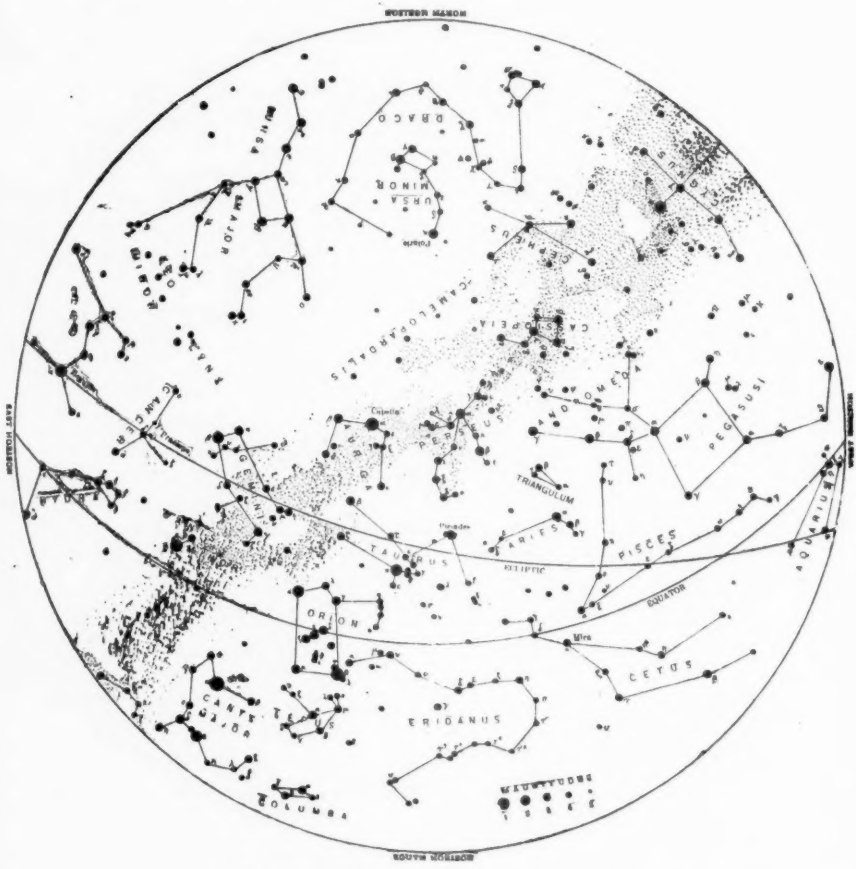
The phases of the moon for this month are as follows:

Full Moon	Jan. 4	at 7 A. M.	C. S. T.
Last Quarter	11	" 2 A. M.	"
New Moon	19	" 5 A. M.	"
First Quarter	27	" 3 A. M.	"

The moon will be nearest the earth on January 4, and farthest from the earth on January 18. The moon is about 31,400 miles nearer at the one time than at the other.

Mercury will be at its greatest elongation west on January 15. It will then be nearly 24° west and a very little south of the sun. It will therefore rise more than an hour before the sun and will be easily visible to the naked eye as a bright and somewhat red object near the horizon. It will be visible during the entire month.

Venus will move eastward a little more rapidly than the sun. It will, however, be more than two and a half hours west of the sun and will continue to be the morning star. It will be decreasing in brilliancy during the month because it is receding from the earth.



THE CONSTELLATIONS AT 9:00 P. M. JANUARY 1, 1912.

The *Earth* will be at its nearest point to the sun on January 3. The earth will then be somewhat more than three million miles nearer the sun than on July 4. The reason that it is warmer in the northern climates when we are farther from the sun than it is when we are near the sun is because the earth is so inclined that the sun shines more directly upon the northern hemisphere at that time.

Mars will move slowly toward the east. It will move less rapidly than the sun and will rise earlier each day. At the end of the month it will be near the meridian at sunset. It will be moving away from the earth again and its angular diameter and also its brightness will be diminishing rapidly.

Jupiter will still be visible in the early morning sky. On January 9 it will differ from Venus about one and one half minutes of time in right ascension and about one degree and forty three minutes of arc in declination. It will be somewhat unusual to have these two bright planets so close to each other.

Saturn will move slowly westward during the first half of the month, and after that slowly toward the east again. It will be in very favorable position for observation. It will be on the meridian at sunset at the end of the month.

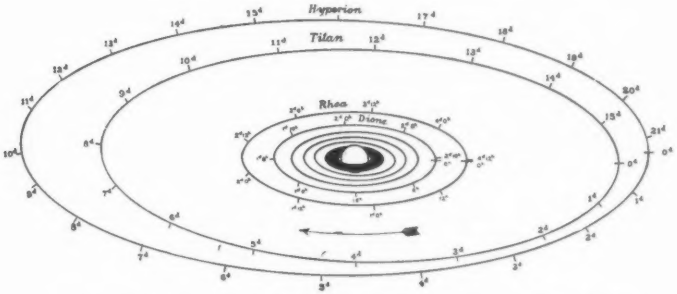
Uranus will be in conjunction with the sun on January 20. It will be very nearly at the same declination also as the sun at this date. It will consequently not be visible during the month.

Neptune will be in opposition with the sun on January 13. It will therefore be on the meridian near midnight throughout the month.

Saturn's Satellites.

CENTRAL STANDARD TIME.

E = eastern elongation; W = western elongation.
I = inferior conjunction; S = superior conjunction.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, at date of opposition, November 23, 1912, as seen in an inverting telescope.

I. Mimas. Period $0^d\ 22^h.6$.

		h			h			h			h
Jan.	1	11.2 W	Jan.	9	11.4 E	Jan.	17	11.7 W	Jan.	26	10.6 E
	2	9.8 W		10	10.0 E		18	10.3 W		27	9.2 E
	3	8.4 W		11	8.7 E		19	8.9 W		28	7.8 E
	4	7.0 W		12	7.3 E		20	7.5 W		29	6.5 E
	5	5.6 W		13	5.9 E		21	6.1 W		30	5.1 E

II. Enceladus. Period $1^d\ 8^h.9$.

Jan.	2	6.6 E	Jan.	10	11.9 E	Jan.	18	17.3 E	Jan.	26	22.6 E
	3	15.5 E		11	20.8 E		20	2.2 E		28	7.5 E
	5	0.4 E		13	5.7 E		21	11.0 E		29	16.4 E
	6	9.3 E		14	14.6 E		22	19.9 E		31	1.3 E
	7	18.2 E		15	23.6 E		24	4.8 E			
	9	3.1 E		17	8.4 E		25	13.7 E			

III. Tethys. Period $1^d\ 21^h.3$.

Jan. 1	23.8 E	Jan. 9	13.0 E	Jan. 17	2.3 E	Jan. 24	15.5 E
3	21.1 E	11	10.3 E	18	23.6 E	26	12.8 E
5	18.4 E	13	7.6 E	20	20.9 E	28	10.1 E
7	15.7 E	15	4.9 E	22	18.2 E	30	7.5 E

IV. Dione. Period $2^d\ 17^h.7$.

Jan. 1	21.0 E	Jan. 10	2.0 E	Jan. 18	7.1 E	Jan. 26	12.2 E
4	14.6 E	12	19.7 E	21	0.8 E	29	5.9 E
7	8.3 E	15	13.4 E	23	18.5 E		

V. Rhea. Period $4^d\ 12^h.5$.

Jan. 4	15.8 E	Jan. 13	16.6 E	Jan. 22	17.5 E	Jan. 31	18.4 E
9	4.2 E	18	5.1 E	27	6.0 E		

VI. Titan. Period $15^d\ 23^h.3$.

Jan. 4	11.9 W	Jan. 12	12.4 E	Jan. 20	10.5 W	Jan. 28	11.3 E
8	8.9 S	16	14.6 I	24	7.7 S		

VII. Hyperion. Period $21^d\ 7^h.6$.

Jan. 3.1 I	Jan. 13.8 S	Jan. 24.3 I	Jan. 29.3 W		
8.1 W	19.3 E				

VIII. Iapetus. Period $79^d\ 22^h.1$.

Jan. 15.8 I	Feb. 4.4 W		

XIX. Phoebe. Period $580^d\ 4^h.7$.

	α Ph.−α Sat. (m)	δ Ph.−δ Sat. (′)		α Ph.−α Sat. (m)	δ Ph.−δ Sat. (′)
Jan. 1	−1 0.1	−5.0	Jan. 21	−1 19.7	−7.4
6	−1 5.4	−5.6	26	−1 23.8	−7.9
11	−1 10.5	−6.2	31	−1 27.5	−8.3
16	−1 15.3	−6.8			

Occultations visible at Washington.

Date 1912	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration h m
Jan. 2	112 B Aurigæ	5.7	15 16	136	15 58	229	0 42
4	4 Cancri	6.2	17 45	84	18 34	315	0 49
6	107 B Leonis	6.3	17 55	106	18 56	320	1 01
22	74 Aquarii	5.8	4 17	80	5 24	203	1 07
25	88 Piscium	6.2	8 52	84	9 53	218	1 01
26	26 B Arietis	6.0	6 20	83	7 31	208	1 11
27	π Arietis	5.2	4 55	80	6 08	212	1 13
27	45 Arietis	6.0	9 23	87	10 31	230	1 08
28	33 Tauri	6.0	11 39	84	12 42	255	1 03
28	161 B Tauri	6.5	13 23	110	14 10	234	0 47
30	136 Tauri	4.6	5 16	59	6 19	275	1 03
30	415 B Tauri	6.1	9 08	135	10 01	219	0 53
31	134 B Gemin.	6.5	13 02	156	13 45	235	0 43

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on Nov 1, 1911.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn
X Androm.	0	10.8	+46	27	12.8	V Can. Min	7	1.5	+ 9	2	8.1
T Cassiop.		17.8	+55	14	11.2*d*	RR Monoc.		12.4	+ 1	17	<13
R Androm.		18.8	+38	1	10.3	U Can. Min.		35.9	+ 8	37	9.2
Y Cephei		31.3	+79	48	<11	U Gemin.		49.2	+22	16	13.8
U Cassiop.		40.8	+47	43	<13	Y Draconis	9	31.1	+78	18	13.1
RW Androm.		41.9	+32	8	<12	R Leonis		42.2	+11	54	8.9*d*
V Androm.		44.6	+35	6	9.6	R Urs. Maj.	10	37.6	+69	18	7.8
RR Androm.		45.9	+33	50	10.2	W Leonis		48.4	+14	15	12.0
RV Cassiop.		47.1	+46	53	14.0	S Leonis	11	5.7	+ 6	0	10.5
W Cassiop.		49.0	+58	1	10.0	T Can. Ven.	12	25.2	+32	3	9.1
U Androm.	1	9.8	+40	11	<13	T Urs. Maj.		31.8	+60	2	12.4
— Androm.		10.4	+41	12	<14	S Urs. Maj.		39.6	+61	38	7.8
S Cassiop.		12.3	+72	5	8.4	U Urs. Min.	14	15.1	+67	15	10.8
S Piscium		12.4	+ 8	24	<13	S Boötis		19.5	+54	16	10.8 *i*
RZ Persei		23.6	+50	20	11.3*d*	R Camelop.		25.1	+84	17	8.7 *i*
R Piscium		25.5	+ 2	22	<12	R Cor. Bor.		44.4	+28	28	8.6
RU Androm.		32.8	+38	10	11.1	X Cor. Bor.		45.2	+36	35	9.6 *i*
Y Androm.		33.7	+38	50	14.0	W Cor. Bor.		11.8	+38	3	11.1
X Cassiop		49.8	+58	46	9.7	U Herculis	16	21.4	+19	7	10.6
R Arietis	2	10.4	+24	35	<10	W Herculis		31.7	+37	32	7.6
Z Cephei		12.8	+81	13	<13	R Draconis		32.4	+66	58	10.9*d*
o Ceti		14.3	— 3	26	7.7*d*	S Herculis		47.4	+15	7	11.1
RR Persei		21.7	+50	49	13.9*d*	R Ophiuchi	17	2.0	−15	58	<10
RR Cephei		29.4	+80	42	<13	Z Ophiuchi		14.5	+ 1	37	10.1
R Triang.		31.0	+33	50	6.0	V Draconis		56.3	+54	53	13.5
W Persei		43.2	+56	34	9.0	W Draconis	18	5.4	+65	56	10.1
U Arietis	3	5.5	+14	25	<12	T Herculis		5.3	+31	0	<11
X Ceti		14.3	— 1	26	12.5*d*	X Draconis		6.8	+66	8	10.5*d*
Y Persei		20.9	+43	50	8.9	W Lyrae		11.5	+36	38	7.7 *i*
R Persei		23.7	+35	20	9.3*d*	SV Draconis		31.2	+49	18	12.5 *i*
W Tauri	4	22.2	+15	49	9.4	RY Lyrae		41.2	+34	34	12.7*d*
R Tauri		22.8	+ 9	56	13.1	R Scuti		42.2	— 5	49	6.6*d*
S Tauri		23.7	+ 9	44	<13	Z Lyrae		56.0	+34	49	11.3*d*
T Camelop.		30.4	+65	57	13.0	S Lyrae	19	9.1	+25	50	13.1
RX Tauri		32.8	+ 8	9	<13	W Aquilae		10.0	— 7	13	12.6
X Camelop.		32.6	+74	56	12.5	TZ Cygni		13.4	+50	0	10.4
R Orionis		53.6	+ 7	59	13.0	U Lyrae		16.6	+37	42	10.5
V Orionis	5	0.8	+ 3	58	12·3	R Cygni		34.1	+49	58	7.9 *i*
R Aurigae		9.2	+53	28	10.1*d*	X Cygni		46.7	+32	40	7.5*d*
S Aurigae		20.5	+34	4	8.8	S Aquilae	20	7.0	+15	19	11.5
W Aurigae		20.1	+36	49	9.2	R Sagittae		9.5	+16	25	9.1
S Camelop		30.2	+68	45	9.2 *i*	RS Cygni		9.8	+38	28	8.2
U Aurigae		35.6	+31	59	<12	R Delphini		10.1	+ 8	47	<11
SU Tauri		43.2	+19	2	9.7	SX Cygni		11.6	+30	46	13.0
Z Tauri		46.7	+15	46	13.0	V Sagittae		15.8	+20	47	10.9
V Camelop.		49.4	+74	30	9.3	U Cygni		16.5	+47	37	9.5
Z Aurigae		53.6	+53	18	11.1	Y Delphini		36.9	+11	31	10.6
SS Aurigae	6	5.8	+47	46	<13	S Delphini		38.5	+16	44	10.1
V Monoc.		17.7	— 2	9	12.5*d*	Y Aquarii		39.2	— 5	12	<14
U Lyncis		31.8	+59	57	12.5	T Delphini		40.7	+16	2	13.5
S Lyncis		35.9	+58	0	9.7 *i*	V Delphini		43.2	+18	58	13.1
R Lyncis		53.0	+55	28	10.0 *i*	T Aquarii		44.7	— 5	31	8.5 *i*

Approximate Magnitudes of Variable Stars on Nov. 1, 1911.

Continued.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
RZ Cygni	20	48.5	+46	59	12.5	S Lacertae	22	24.6	+39	48	8.7
RVulpeculae		59.9	+23	26	8.3	R Lacertae		38.8	+41	51	8.8
TW Cygni	21	1.8	+29	0	11.3	S Aquarii		51.8	−20	53	13.0
X Cephei		3.6	+82	40	<13	RW Pegasi		59.2	+14	46	12.3
T Cephei		8.2	+68	5	7.4*d*	R Pegasi	23	1.6	+10	0	8.9*d*
R Equulei		8.4	+12	23	14.0	V Cassiop.		7.4	+59	8	11.4 *i*
S Cephei		36.5	+78	10	10.3	ST Androm.		33.8	+35	13	8.7 *i*
SS Cygni		38.8	+43	8	8.1	R Aquarii		38.6	−15	50	9.5
V Pegasi		56.0	+ 5	38	13.1	Z Cassiop.		39.7	+56	2	<13
RT Pegasi		59.8	+34	38	9.6	R Cassiop.		53.3	+50	50	10.5
T Pegasi	22	4.0	+12	3	14.2	SV Androm.		59.2	+39	33	<12

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled at the Harvard College Observatory from observations made at the Amherst, Hoge, Hunter, Jacobs Mt. Holyoke, Olcott, Swartz, Vassar and Vrooman observatories.

Minima of Variable Stars of the Algol Type.

[Calculated by Mary H. Wilson at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard 6^h, etc.

Star	R. A. 1900 h	m	Decl. 1900 °	′	Magnitude	Approx Period d	h	Greenwich mean times of minima in **January** 1912. d h	d h	d h	d h
SY Androm.	0	08.0	+43	09	9.5—13.0	34	21.6				
UU Androm.		38.5	+30	24	10.7—11.9	1	11.7	8 22;	14 21;	20 19;	26 18
U Cephei	0	53.4	+81	20	7.1— 9.2	2	11.8	5 10;	10 10;	20 09;	30 08
Z Persei	2	33.7	+41	46	9.4—12.	3	01.4	6 12;	12 14;	18 17;	24 20
RY Persei		39.0	+47	43	8.0—10.3	6	20.7	8 23;	15 20;	22 17;	29 14
RZ Cassiop.		39.9	+69	13	6.4— 7.8	1	04.7	4 12;	10 11;	16 11;	22 10
ST Persei		53.7	+38	47	8.5—10.5	2	15.6	7 05;	12 13;	17 20;	23 03
RX Cephei	2	58.8	+67	11	8.6— 9.1	32	07.6	15 18			
Algol	3	01.7	+40	34	2.3— 3.5	2	20.8	6 14;	12 07;	18 01;	23 19
RT Persei		16.7	+46	12	9. —11.	0	20.4	6 11;	11 13;	21 18;	31 22
λ Tauri		55.1	+12	12	3.4— 4.5	3	22.9	1 19;	9 17;	17 14;	25 12
RW Tauri	3	57.8	+27	51	7.1—<11	2	18.5	3 05;	8 18;	19 20;	30 22
RV Persei	4	04.2	+33	59	10.6—12.8	1	23.4	7 02;	13 00;	18 22;	24 20
RW Persei		13.3	+42	04	8.8—11.0	13	04.8	8 23;	22 04		
RS Cephei	4	48.6	+80	06	9.5—12.2	12	10.1	11 08;	23 18		
RY Aurigæ	5	11.5	+38	13	10.7—11.7	2	17.5	7 11;	12 22;	18 09;	23 20
RZ Aurigæ		42.9	+31	40	10.6—13.3	3	00.3	5 05;	11 06;	17 06;	23 07
SV Gemin;		54.6	+24	28	9.8—<11	4	00.2	5 18;	13 19;	21 19;	29 19
RW Gemin.	5	55.4	+23	08	9.5—11.0	2	20.8	3 21;	9 15;	15 08;	21 02
U Columbæ	6	11.2	−33	03	9.4—10.2	2	19.2	6 15;	12 05;	17 19;	23 10
56.1908 Gem.		22.	+20	37	10.8—11.5	1	08.8	6 13;	12 00;	17 11;	22 23
RW Monoc.		29.3	+ 8	54	9.0—10.8	1	21.7	1 18;	9 09;	17 00;	24 15
RX Gemin.		43.6	+33	21	8.8— 9.6	12	05.0	8 14;	20 19		
RU Monoc.	6	49.4	− 7	28	9.8—10.5	0	21.5	7 13;	12 22;	18 07;	23 16
R Canis Maj.	7	14.9	−16	12	5.9— 6.7	1	03.3	3 11;	9 03;	14 20;	26 04
RY Gemin.		21,7	+15	52	8.9—<10	9	07.2	8 10;	17 17;	27 00	
Y Camelop		27.6	+76	17	9.5—12.	3	07.3	5 0;	11 14;	18 05;	24 20
RR Puppis		43.5	−41	08	9.5—	6	10.3	5 5;	11 15;	18 02;	24 12

Minima of Variable Stars of the Algol Type.—Continued.

Star	R. A. 1000	Decl. 1900	Magnitude	Period	Greenwich mean times of maxima in **January** 1912.
	h m	° ′		d h	d h d h d h d h d h
V Puppis	7 55.4	−48 58	4. — 5.	1 10.9	4 11; 11 17; 18 24; 26 07
X Carinæ	8 29.1	−58 53	7.8— 8.9	0 13.0	9 5; 14 15; 20 01; 25 11
S Cancri	8 38.2	+19 24	8. −10.	9 11.6	8 5; 17 16; 27 04
S Velorum	9 29.5	−44 46	7.8— 9.5	5 22.4	4 02; 10 00; 15 22; 21 21
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	1 10; 9 20; 18 07; 26 17
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	5 02; 14 8; 23 15
SS Carinæ	10 54.2	−61 23	12.2—12.8	3 07.2	6 13; 13 03; 19 17; 26 08
RW Urs. Maj	11 35.4	+52 34	9.3—10.3	7 07.9	3 02; 10 10; 17 18; 25 02
Z Draconis	11 40.6	+72 49	9.5—12.5	1 08.6	6 01; 12 20; 19 15; 26 10
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	2 14; 10 00; 17 11; 24 21
δ Libræ	14 55.6	− 8 07	5. — 6.7	2 07.9	8 05; 15 04; 22 04; 29 03
U Coronæ	15 14.1	+32 01	7.8— 9.0	3 10.9	4 05; 11 03; 18 00; 24 22
TW Draconis	15 32.4	+64 14	7.0— 8.9	2 19.4	1 05; 9 15; 18 01; 26 11
SW Ophiuchi	16 11.1	− 6 44	9.2—10.	2 10.7	1 22; 9 06; 16 14; 23 22
SX Ophiuchi	16 12.6	− 6 25	10.5—11.2	2 01.5	2 04; 8 08; 14 13; 20 18
R Aræ	16 31.1	−56 48	6.7— 8.	4 10.2	4 04; 13 00; 21 21; 30 17
TT Herculis	16 49.9	+17 00	8.9— 9.5	20 18.1	17 05;
TU Herculis	17 09.8	+30 50	9.5—12.	2 06.4	3 00; 9 20; 16 15; 23 10
U Ophiuchi	11.5	+ 1 19	6. — 6.7	0 20.1	1 20; 10 05; 18 14; 26 23
SZ Herculis	17 36.0	+33 01	9 5—10.3	0 19.6	1 07; 9 12; 17 16; 25 20
Z Herculis	17 53.6	+15 09	6.7— 8.0	3 23.8	0 21; 8 21; 16 21; 24 20
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	10 07; 15 11; 20 15; 25 19
RS Sagittarii	11.0	−34 08	6.7— 7.8	2 10.0	3 04; 10 10; 17 16; 24 22
V Serpentis	11.1	−15 34	9.5—	3 10.9	5 07; 12 04; 19 02; 26 00
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	7 15; 13 03; 18 15; 24 04
RX Herculis	26.0	+12 32	7.8— 8.0	0 21.3	2 06; 11 04; 20 01; 28 22
SX Sagittarii	39.7	−30 36	8.6— 9.4	2 01.8	8 12; 14 18; 21 00; 27 05
RR Draconis	40.8	+62 34	9.3—13.	2 19.9	2 19; 11 07; 19 19; 28 06
RS Scuti	43.7	−10 21	9.3—10.3	0 15.9	8 04; 14 19; 21 09; 28 00
U Scuti	18 48.9	−12 44	9.0— 9.8	0 22.9	2 16; 12 05; 21 19; 31 08
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.5	3 21; 13 08; 22 19
RV Lyræ	12.5	+32 15	11. −13.	3 14.4	6 09; 13 13; 20 18; 27 23
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	4 12; 13 10; 22 09; 31 08
U Sagittæ	14.4	+19 26	6.7— 9.0	3 09.1	6 23; 13 17; 20 11; 27 05
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	5 04; 12 13; 19 21; 27 07
136.1910 Lyræ	24.3	+41 30	9.0<11.0	5 05.8	5 23; 11 05; 16 11; 21 17
SY Cygni	19 42.7	+32 28	10. −12.	6 00.2	5 18; 11 18; 17 18; 23 19
WW Cygni	20 00.6	+41 18	9.5—12.5	3 07.6	7 21; 14 12; 21 03; 27 19
SW Cygni	03.8	+46 01	9. −12.	4 13.8	3 17; 12 20; 22 00; 31 03
VW Cygni	11.4	+34 12	9.5—11.5	8 10.3	7 22; 15 08; 23 18
RW Capric.	12.2	−17 59	8.8—10.6	3 09.4	10 01; 16 20; 23 15; 30 09
UW Cygni	19.6	+42 55	10.5—13.	3 10.8	8 15; 15 12; 22 10; 29 08
W Delphini	33.1	+17 56	9.5—11.5	4 19.4	2 08; 11 23; 21 13; 31 04
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	4 19; 14 00; 23 05
Y Cygni	48.1	+34 17	7. — 8.	1 12.0	2 5; 9 17; 17 04; 24 16
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	1 11; 11 13; 21 16; 31 18
VV Cygni	21 02.3	+45 23	11. −14.	1 11.4	2 22; 10 07; 17 16; 25 02
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	4 18; 14 10; 24 03; 29 23
UZ Cygni	55.2	+43 52	9. −11.5	31 07.3	4 06
RT Lacertæ	21 57.4	+43 24	9.1—10.5	5 01.7	4 17; 9 18; 19 22; 30 01
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	7 04; 12 09; 22 18; 27 22
TT Androm	23 08.7	+45 36	10.5—11.3	2 18.3	3 00; 11 07; 19 14; 27 21
32.1911 Pisc.	29.3	+ 7 22	9.0—12.0	3 18.4	4 02; 11 15; 19 04; 26 16
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	2 05; 10 11; 18 17; 26 23

Maxima of Variable Stars of Short Period not of the Algol Type.

[Calculated by Wallace F. Johnson at Goodsell Observatory]

Given to the nearest hour in Greenwich mean time. To obtain eastern standard time subtract 5^h; Central standard time 6^h etc. An * following the name of a star signifies that for that star times of minima instead of maxima are given.

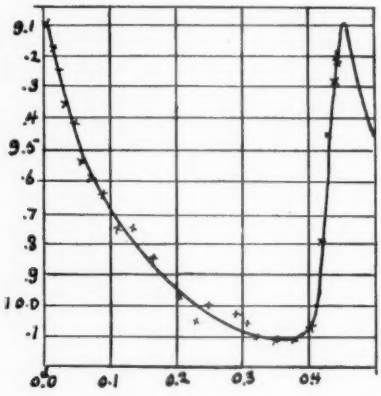
Star	R. A. 1900	Decl. 1900	Magnitude	Period	Greenwich mean times of maxima in **January** 1912.
	h m	° ′		d h	d h d h d h d h
SX Cassiop.	0 05.5	+54 20	8.6— 9·4	36 13.7	9 02
SY Cassiop.	9.8	+57 52	9 3— 9.9	4 1.7	7 09; 15 13; 23 16; 31 20
RT Sculptor.*	0 31.5	−26 13	9.6—10.5	0 12.3	7 17; 12 20; 17 23; 23 02
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	7 09; 12 22; 18 11; 23 23
RW Cassiop.	1 30.7	+57 15	8.6— 9.4	14 19 2	13 17; 28 12
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	6 11; 12 10; 18 09; 24 08
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	5 20; 11 16; 17 12; 23 08
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	5 15; 11 17; 17 19; 23 20
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	7 00; 23 00
SX Persei	4 10.2	+41 29	10.3—11.0	4 07.1	5 03; 13 17; 22 07
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	8 21; 20 00; 31 03
RX Aurigæ	4 54.5	+39 49	7.2— 8.1	11 15.0	6 10; 18 01; 29 16
TT Aurigæ*	5 02.8	+39 27	7.8— 8.7	0 16.0	3 18; 10 10; 17 02; 23 18
SX Aurigæ	04.6	+42 02	8.0— 8.7	1 12.8	7 12; 13 15; 19 18; 25 21
SY Aurigæ	05.5	+42 42	9.0— 9.7	10 03.3	2 15; 12 19; 22 22
Y Aurigæ	21.5	+42 21	9. —	3 20.6	1 03; 8 20; 16 14; 24 07
SV Tauri*	45.8	+28 05	9.4—11.0	2 04.0	2 22; 9 10; 15 22; 22 10
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	5 19; 11 07; 16 20; 22 09
RS Orionis	6 16.5	+14 43	7·8— 8.5	7 13.4	5 08; 12 21; 20 11; 28 00
T Monoc.	19.8	+ 7 08	6. — 8.	27 00.3	10 01
57.1908 Gem.	23.7	+67 06	11.0—12.8	0 11.5	8 02; 12 21; 17 17; 22 12
W Gemin.	29.2	+15 24	6.8— 7.6	7 22.0	7 04; 15 02; 23 00; 30 22
ζ Gemin.	6 58.2	+20 43	3.7— 4.5	10 03.7	1 08; 11 12; 21 16; 31 19
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5	21 21
RR Gemin.	7 15.2	+31 04	9.7—10.6	0 09.5	3 15; 11 13; 19 12; 27 11
V Carinæ	8 26.7	−59 47	7.2— 8.0	6 16.7	3 09; 10 02; 16 18; 23 11
T Velorum	8 34.4	−47 01	7.5— 8.5	4 15.3	9 11; 14 02; 18 18; 23 09
W Carinæ	9 19.2	−55 32	7.5— 8.5	4 08.9	3 16; 12 09; 21 03; 29 21
S Antliæ*	27.9	−28 11	6.7— 7.8	0 07.8	1 08; 7 19; 14 07; 20 19
W Ursæ Maj.	9 36.7	+56 24	8.	0 04.0	3 13; 10 05; 16 21; 23 13
RR Leonis	10 02.1	+24 03	9.1—10.0	0 10.9	9 21; 16 16; 23 11; 30 05
ST Ursæ Maj.*	11 22.4	+45 44	6.7— 7.2	8 19.2	6 05; 15 00; 23 19
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	7 20; 14 11; 21 01; 27 16
S Muscae	12 07.4	−69 36	6.5— 7.3	9 15.8	1 19; 11 11; 21 03; 30 19
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	8 13; 14 06; 19 23; 25 15
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	8 23; 15 17; 22 11; 29 04
R Crucis	18.1	−61 04	6.8— 8.0	5 19.8	5 16; 11 12; 17 08; 23 04
S Crucis	48.4	−57 53	6.6— 7.8	4 16.6	9 23; 14 16; 19 08; 24 01
RZ Centauri	12 55.6	−64 05	8.5— 8.9	0 22.5	4 00; 11 12; 19 00; 26 13
W Virginis	13 20.9	− 2 52	9.0—10.0	17 06.5	7 10; 24 17
RV Ursæ Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	4 01; 11 01; 18 02; 25 02
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	5 10; 13 15; 21 21; 30 02
V Centauri	25.4	−56 27	6.7— 7.6	5 11.9	7 16; 13 04; 18 16; 24 04
RU Bootis	14 29.3	+32 11	8.9—10.	0 09.1	3 17; 11 06; 18 19; 26 08
RTriang.Austr	15 10.8	−66 08	6.7— 7.7	3 09.3	5 12; 12 06; 19 01; 25 20
STriang.Austr	15 52.2	−63 29	6.5— 7.5	6 07.8	9 15; 15 23; 22 07; 28 15
S Normæ	16 10.6	−57 39	6.5— 7.4	9 18.1	6 08; 16 02; 25 20
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	7 09; 16 05; 25 02
RV Scorpii	16 51.8	−33 27	6.8— 7.6	6 01.5	7 00; 13 02; 19 03; 25 05
u Herculis*	17 13.6	+33 12	5.1— 5.6	2 01.2	5 20; 12 00; 18 03; 24 07

Maxima of Variable Stars of Short Period not of the Algol Type.

Star	R. A. 1900	Decl. 1900	Magnitude	Period	Greenwich mean times of maxima in January 1912.
	h m	° ′		d h	d h d h d h d h
RV Ophiuchi*	17 29.8	+ 7 19	9.—< 11	3 16.5	5 00; 12 09; 19 18; 27 03
X Sagittarii	41.3	−27 48	4.0— 6.0	7 00.3	7 08; 14 08; 21 08; 28 09
Y Ophiuchi	47.3	− 6 07	6.2— 7.0	17 02.9	9 19; 26 22
W Sagittarii	17 58.6	−29 35	4.8— 5.8	7 14.3	3 16; 11 07; 18 21; 26 11
Y Sagictarii	18 15.5	−18 54	5.8— 6.6	5 18.6	4 18; 10 13; 16 08; 22 02
U Sagittarii	26.0	−19 12	7.0— 8.3	6 17.9	4 21; 11 15; 18 08; 25 02
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	9 00; 19 09; 29 17
Y Lyrae	34.2	+43 52	10.5—12.	0 12.1	7 19; 13 20; 18 21; 25 21
RZ Lyrae	39.9	+32 42	9.9—11.2	0 12.3	4 08; 9 10; 19 16; 29 21
RT Scuti	44.1	−10 30	9.1— 9.7	0 11.9	2 08; 7 07; 17 05; 27 03
β Lyrae *	46.4	+33 15	3.4— 4.5	12 21.8	9 05; 22 03
κ Pavonis	18 46.9	−67 22	4.0— 5.5	9 02.2	9 13; 18 15; 27 17
U Aquilae	19 24.0	− 7 15	6.4— 7.1	7 00.6	4 17; 11 18; 18 18; 25 19
XZ Cygni	30.4	+56 10	8.7— 9.3	0 11.2	1 08; 10 16; 20 00; 29 08
U Vulpec.	32.2	+20 07	6.9— 7.6	7 23.5	1 06; 9 06; 17 05; 25 05
SU Cygni	40.8	+29 01	6.6— 7.4	3 20.3	7 19; 15 11; 23 04; 30 21
η Aquilae	47.4	+ 0 45	3.5— 4.7	7 04.2	3 18; 10 22; 18 02; 25 07
S Sagittae	51.5	+16 22	5.6— 6.4	8 09 2	1 18; 10 03; 18 12; 26 22
X Vulpec.	19 53.3	+26 17	8.5— 9.1	6 07.7	2 01; 8 08; 14 16; 21 00
XX Cygni	20 01.3	+58 40	10.5—11.5	0 03.2	2 18; 9 12; 16 06. 22 23
V Vulpec. *	32.3	+26 15	8.0— 9.0	37 19.0	
X Cygni	39.5	+35 14	6.4— 7.7	16 09.3	13 22; 30 08
T Vulpec.	47.2	+27 52	5.5— 6.5	4 10 5	1 16; 10 13; 19 10; 28 07
WZ Cygni *	49.3	+38 27	9.8—10.8	0 14.0	5 17; 11 13; 17 09; 23 06
UY Cygni	52.3	+30 03	9.5—10.3	0 13.5	3 22; 9 13; 20 18; 31 23
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	4 07; 13 06; 22 05; 31 04
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	11 20; 26 13
VY Cygni	21 00.4	+39 34	8.9— 9.5	7 20.6	2 15; 10 11; 18 08; 26 05
VZ Cygni	21 47.7	+42 40	8.4— 9.2	4 20.7	4 03; 9 00; 18 18; 28 11
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.6	4 11; 13 03; 21 19; 30 10
δ Cephei	25.5	+57 54	3.7— 4.9	5 08.8	6 00; 11 09; 16 17; 22 02
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1	9 03; 20 00; 30 21
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	7 07; 13 17; 20 03; 26 13
V Lacertae	44.5	+55 48	8.2— 8.9	4 23.6	5 06; 10 05; 20 04; 30 04
X Lacertae *	22 45.0	+55 54	8.2— 8.6	5 10.6	2 16; 8 03; 19 00; 29 21
SW Cassiop.	23 03.7	+58 12	9.2— 9.7	5 10.6	4 14; 10 00; 20 21; 31 18
RS Cassiop.	32.6	+61 52	9.1—10.0	6 07.1	2 04; 8 11; 14 19; 21 02
RY Cassiop.	47.2	+58 11	9 2—10.0	12 03.4	4 16; 16 19; 28 23
U Pegasi	23 52.9	+15 24	9.0— 9.7	0 04.5	2 06: 9 18; 17 06; 24 18

Change in Form of the Variable Star Tables.—Will those of our readers who make use of the tables of minima and maxima of short period variable stars please notice the change in form this month and tell us if they like the change. It has become too much of a burden to calculate and print the times of individual minima and maxima so we have for next year sought to give to the nearest hour the times of four epochs each month for each star, when the period is under seven days. In the form now chosen the right ascension, declination, magnitudes and approximate period of each star are given and the part of each page giving these data can be left standing from month to month, so that the printing is not expensive. We have tried to keep our table of elements up to date and the computations have been made to the nearest minute and double checked at the beginning and end of the year. Anyone who wishes the ephemeris of any particular star for accurate comparison with his observations may have it by writing to the editor.

New Elements and Light Curve of RR Leonis:—In *A.N.* 4532 Mr. M. Luizet determines new elements of the variable RR Leonis. He finds the period to be only about one tenth of that found in 1909. The star is of the δ Cephei

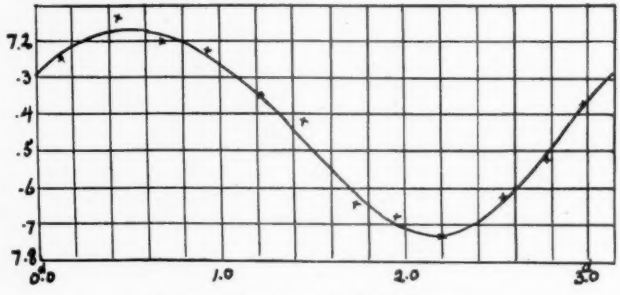


LIGHT CURVE OF RR LEONIS.

type, the rise from minimum to maximum occupying only $2^h\ 5^m$. The period is $10^h\ 51^m\ 24^s.6$ and the magnitudes at maximum and minimum 9.1 and 10.1, respectively. The new elements are

$$\text{Max.} = 2418120.357 \text{ Paris M. T.} + 0^d.452368\ E.$$

Light Curve of the Variable 41.1910 Tauri:—In *A. N.* 4532 Professor K. Schwarzschild discusses a series of observations of this variable made at Göttingen in 1906-1909 and at Potsdam in 1909-1910 and finds the



LIGHT CURVE OF 41.1910 TAURI.

period to be 3.1484 days. The star varies continuously, the curve being perfectly symmetrical, and the range being between magnitudes 7.17 and 7.73. The elements are

$$\text{Minimum} = 2418724^d.16 \text{ M. E. T.} + 3^d.1484\ E.$$

New Elements of Z Leonis:—In *A. N.* 4532 Mr. M. Luizet gives the following new elements of Z Leonis.

$$\text{Max.} = 2418060.0 + 56^d.36\ E$$
$$\text{Min.} = 2418036.2 + 56\ .36\ E$$

The extremes of brightness are not always the same, the star ranging from 8.3 to 7.9 at different maxima and from 9.1 to 9.6 at different minima.

New Variable Star 44.1911 Cygni.—This is announced in *A. N.* 4531 by Professor A. Abetti of Arcetri-Firenze. It is BD + 42° 3991 ($9^m.5$) and was found on August 20 to be as faint as magnitude 12. The position for 1900 is

$$\alpha = 21^h\ 06^m\ 23^s.5 \qquad \delta = +43°\ 07'.1$$

New Variable Star 45.1911 Cassiopeiæ:—This is announced by Mr. T. H. Astbury in *A. N.* 4532. The star is BD + 58°30 and is recorded in the BD as of magnitude 7.3. On 1911 September 18 at $8^h\ 55^m$ Gr. M. T. and again on October 8, at $9^h\ 05^m$ Mr. Astbury found the star much fainter than usual. It was at its normal brightness October 1, 3 and 9, so that it is perhaps of the Algol type.

Elements of Variable Stars:—In his fifth publication of Variable star observations made at Dombaas, Norway, Mr. Sigurd Enebo gives the following table of elements of 19 stars, determined from his own and other observations:

Star	Elements	Greenwich M. T.	M—m	Amplitude
		d d	d	m m
TT Cassiop.	Max.=	2418588. +377. E	—	10.0—<13.0
S Trianguli	Max.=	9036. +254	—	9.0— 12.3
SW Persei	Max.=	7520. +(161—E)E	—	8.4— 9.6
SX Persei	Max.=	8240.25 + 4.290 E	1.3	10.4— 11.2 *
TV Aurigæ	Max.=	8970. +361 E	—	8.8— 10.0 †
RW Aurigæ			—	9.0—<12.0 ‡
SY Aurigæ	Max.=	7833.4 + 10.137 E	—	8.4— 9.4
TW Aurigæ			—	8.2— 9.3 ¶
RZ Gemin.	Max.=	8313.33 + 5.5275 E	1.1	9.1— 10.0 ‖
SS Gemin.	Max.=	8288. + 44.6 E	20.	8.2— 9.3
40.1906 Gem.	Min. =	8683. +698 E	—	9.1— 10.6 §
RZ Ursae Maj.	Max.=	8358. +229 E	6.0—8.0	8.7— 9.8
SU Draconis	Max.=	7981.25 + 0.660414 E	—	8.8— 9.6**
W Draconis	Max.=	3013. +244.1 E		
		+8.3 sin (280°+7°.5E)E	—	9.0—<14.0
X Draconis	Max.=	2256. +257.8 E	—	9.2—<14.0
SV Draconis	Max.=	8611. +251 E	—	8.7—<12.0
AD Cygni				8.8— 9.7††
SS Pegasi	Max.=	8865. +412 E	190	>8.7—<12.5
SW Cassiop.	Max.=	2417809.2 + 5.44 E	2	9.0— 9.9‡‡

* δ Cephei type. † Period changes. ‡ Irregular. ¶ Irregular. ‖ δ Cephei type. § Max. less sharp. ** Antalgol-type. †† Irregular. ‡‡ δ Cephei Type.

COMET AND ASTEROID NOTES.

Photographs of Comets.—We are indebted to Dr. H. D. Curtis and Mr. C. C. Kiess of the Lick Observatory for some splendid prints from photographs of Brooks' comet *c* 1911 (See plates XXVII, XXVIII and XXIX.) They show a wonderful amount of detail in the structure of the head and tail of the comet. The photograph of Beljawsky's comet is not so good, having been obtained with difficulty against a bright background of sky light at a low altitude, but it also shows considerable detail in the structure of the head of that comet.

Three Comets are now within reach of small telescopes in the southern hemisphere, Brooks', Borrelly's and Quénisset's. Kiess comet *b* 1911 is becoming very faint but may be followed by southern observers with large instruments. Beljawsky's and Encke's are unfavorably situated with reference to the sun. Quénisset's too is getting too near the sun but can still be observed by northern as well as southern observers. Brooks' comet *c* 1911 may also be seen by southern observers in the morning and is barely visible to the naked eye. Borrelly's comet is coming north and is now at about its brightest. It will cross the equator, in the constellation Cetus, a little way southwest of α Ceti, on December 13. Its course from there on is almost due north for the rest of the month. At its brightest it will be only a telescopic comet.

Comets *c* and *g* 1911.—Telegrams have been received at this Observatory from Dr. Joel Stebbins of the Observatory at Urbana, Ill., stating that the brightness of Brooks' comet has greatly increased in twenty-four hours—the head of the comet being of the second magnitude and the tail twenty degrees long.

A letter from Professor Frost, Director of the Yerkes Observatory, and dated October 18, 1911, gives the following information relative to Beljawsky's comet.

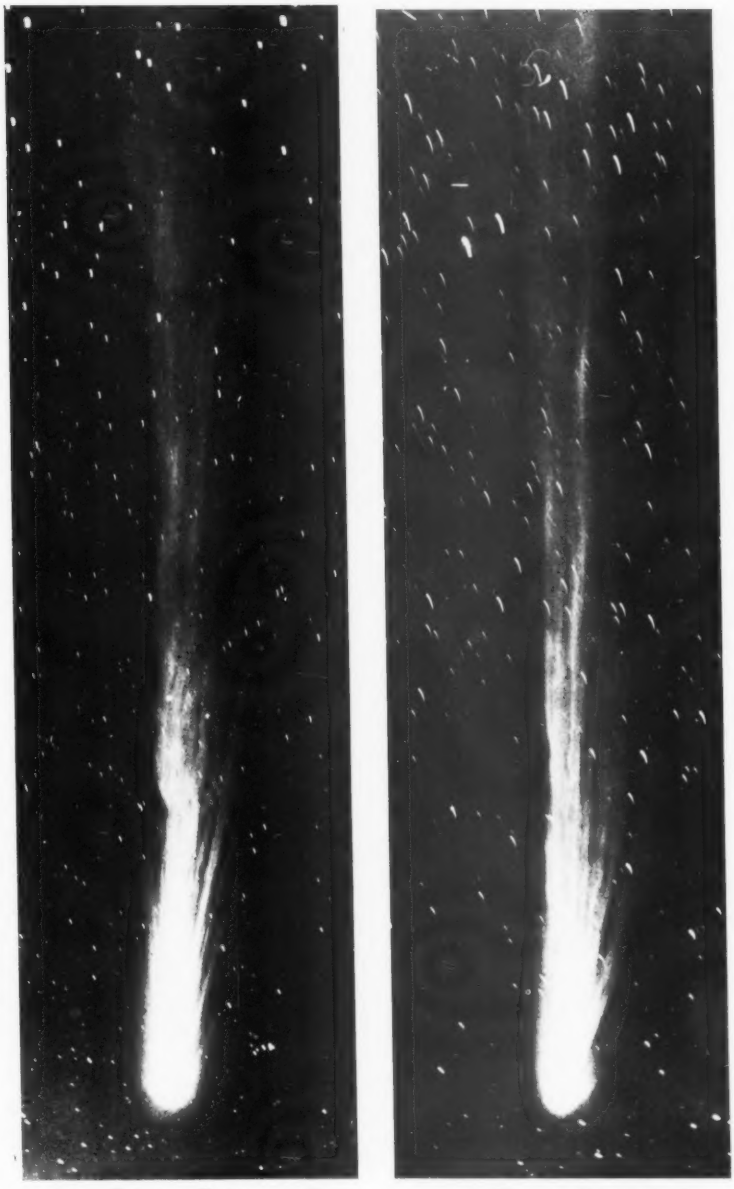
Rough pointings by Barnard on October $17^d\ 11^h\ 45^m$ G.M.T., placed the comet in R. A. $14^h\ 30^m.4$ and Dec. $+2°\ 12'$. One photograph shows a tail ten degrees in length. Three degrees of tail seen in field-glass. Two spectrograms by Parkhurst showed six bands in all. The carbon band at λ 474 being the strongest and the cyanogen band at λ 3883 being the next in intensity. Spectrum of the tail showed for one half a degree.

EDWARD C. PICKERING.

Harvard College Observatory.
Astronomical Bulletin, No 474.
October 20, 1911.

Comet *g* 1911 Beljawsky was observed at Algiers on October 17. It was then as bright as a second magnitude star. The comet is now far away on the other side of the sun.

PLATE XXVII.



1911 Oct. 21. Exposure 40m
Negative by Herber D. Curtis with
Willard lens.

1911 Nov. 4. Exposure 1h
Negative by C. C. Kiess with
Dallmeyer lens.

PHOTOGRAPHS OF BROOKS' COMET TAKEN AT THE LICK OBSERVATORY.

Ephemeris of Comet c 1911 (Brooks).
[From Astronomische Nachrichten 4534.]

Berlin Midnight 1911		α h	m	s	δ °	′	log r	log Δ	Mag. m
Dec.	1	13	35	8	−29	22.1			
	2		37	25	29	58.5			
	3		39	41	30	34.1			
	4		41	57	31	8.8			
	5		44	12	31	42 8			
	6		46	26	32	16.0	0.0077	0.1817	5.9
	7		48	39	32	48.5			
	8		50	51	33	20.3			
	9		53	2	33	51.5			
	10		55	12	34	22.0			
	11		57	21	34	51.9			
	12	13	59	29	35	21.2			
	13	14	1	35	35	50.0			
	14		3	41	36	18.2	0.0631	0.2094	6.3
	15		5	46	36	45.9			
	16		7	49	37	13.0			
	17		9	51	37	39.7			
	18		11	52	38	5.9			
	19		13	52	38	31.7			
	20		15	50	38	57.0			
	21		17	46	39	21.9			
	22		19	42	39	46.3	0.1114	0.2321	6.7
	23		21	36	40	10.4			
	24		23	29	40	34.1			
	25		25	20	40	57.4			
	26		27	10	41	20.3			
	27		28	58	41	42.9			
	28		30	45	42	5.1			
	29		32	30	42	27.0			
	30		34	14	42	48.7	0.1541	0.2508	7.0
	31		35	56	43	10.0			
Jan.	1		37	37	43	31.1			
	2		39	16	43	51.9			
	3		40	54	44	12.4			
	4		42	29	44	32.7			
	5		44	4	44	52.7			
	6		45	36	45	12.5			
	7	14	47	8	−45	32.1	0.1922	0.2660	7.3

Ephemeris of Comet e 1911 (Borrelly).
[From Astronomische Nachrichten 4533.]

Paris Midnight 1911		α app. h	m	s	δ app. °	′	log r	log Δ	1:r²Δ²
Dec.	1	3	1	41	−12	43.2	0.1508	9.7095	1.90
	3	2	58	58	10	42.3			
	5		56	25	8	36.8	0.1492	9-7065	1.94
	7		54	2	6	28.0			
	9		51	52	4	16.7	0.1480	9.7073	1.95
	11		49	53	− 2	3.9			
	13		48	7	+ 0	9.3	0.1472	9.7121	1.91
	15		46	34	2	22.6			
	17		45	15	4	35.4	0.1470	9.7207	1.84
	19		44	10	6	46.9			
	21		43	21	8	56.0	0.1471	9.7328	1.74
	23		42	48	11	2.8			
	25		42	30	13	6.8	0.1478	9.7479	1.62
	27		42	26	15	7.5			
	29		42	36	17	4.4	0.1488	0.7653	1.49
	31	2	42	58	+18	57.1			

Ephemeris of Comet *f* 1911 (Quenisset.)

[From Astronomische Nachrichten 4534.]

Berlin Midnight 1911	α h	m	s	δ °	′	log *r*	log Δ	Mag. m
Dec. 1	15	47	45	− 9	39.2			
2		47	48	10	19.8			
3		47	52	11	0.1	9.9469	0.2527	7.6
4		47	56	11	40.2			
5		48	0	12	20.1			
6		48	4	12	59.9			
7		48	9	13	39.5	9.9645	0.2570	7.7
8		48	15	14	19.0			
9		48	19	14	58.3			
10		48	24	15	37.5			
11		48	29	16	16.6	9.9833	0.2599	7.8
12		48	34	16	55.6			
13		48	39	17	34.6			
14		48	44	18	13.5			
15		48	49	18	52.3	0.0027	0.2614	7.9
16		48	54	19	31.1			
17		48	58	20	9.8			
18		49	3	20	48.6			
19		49	8	21	27.3	0.0223	0.2617	8.0
20		49	13	22	6.1			
21		49	18	22	44.8			
22		49	22	23	23.6			
23	15	49	27	−24	2 4	0.0419	0.2610	8.1

Ephemeris of Comet *g* 1911 (Beljawsky).

[From Astronomische Nachrichten 4534.]

Berlin Midnight 1911	α h	m	m	δ °	′	log *r*	log Δ	Mag. m
Dec. 1	17	9	15	−30	54.5	0.1142	0.3506	7.2
3		13	17	31	34:2			
5		17	14	32	12.2	0.1382	0.3658	7.4
7		21	7	32	48.8			
9		24	57	33	23.9	0.1605	0.3798	7.6
11		28	44	33	57.7			
17		32	27	34	30.4	0.1814	0.3926	7.8
15		36	8	35	2.0			
17		39	45	35	32.6	0.2009	0 4043	7.9
19		43	19	36	2.3			
21		46	51	36	31.1	0.2194	0 4149	8.1
23		50	20	36	59.2			
25		53	47	37	26.6	0.2368	0.4246	8.2
27	17	57	11	37	53.4			
29	18	0	32	38	19.6	0.2533	0.4335	8.3
31		3	51	38	45.3			
Jan. 2		7	7	39	10.5	0.2690	0.4415	8.5
4		10	21	39	35.2			
6	18	13	33	−39	59.4	0.2839	0.4488	8.6

PLATE XXVIII.

PHOTOGRAPH OF THE HEAD OF BROOKS' COMET *c* 1911 TAKEN AT THE LICK OBSERVATORY BY HEBER D. CURTIS, 1911 OCTOBER 21.

Exposure 40^m with the Crossley Reflector.

PLATE XXIX.

Head of Brooks' Comet *c* 1911, Oct. 22. Exposure 54^m

Head of Beljawsky's Comet *g* 1911, Oct. 19. Exposure 19^m

PHOTOGRAPHS TAKEN AT THE LICK OBSERVATORY, WITH THE CROSSLEY REFLECTOR BY HEBER D. CURTIS.

POPULAR ASTRONOMY, No. 190.

A Remarkable Asteroid.—A very remarkable object has recently been discovered by Palisa and confirmed by Pecüle. Its position is given in the Astron. Nach. 189, pp. 295 and 311, as

Vienna M. T.				α app.			δ app.			Magn.
	d	h	m	h	m	s	°	′	″	
1911 Oct.	3	14	54.4	0	42	5.13	+0	15	38	12.0

Daily motion in R. A. $+2^m\ 8^s$ in Dec. $-32'$

Copenhagen M. T.				α app.			δ app.			Magn.
	d	h	m	h	m	s	°	′	″	
1911 Oct.	4	14	11.0	0	43	59.0	−0	17	49	12.3

No announcement of the discovery was received by cablegram from the Centralstelle but I have asked by cable for the latest position and will telegraph this as soon as received. The object is not retrograding but advancing in right ascension by about half a degree daily and going south by the same amount. It must therefore be near the earth, near perihelion and have a large eccentricity. Additional observations of this object are urgently needed, and should be sent here at once by telegram.

EDWARD C. PICKERING.

Astronomical Bulletin No. 475.
Harvard College Observatory,
October 24 1911.

No later observations of the remarkable asteroid have been obtained so far as has been reported and it is therefore probably lost, at least for the present apparition. A supposed observation at Greenwich on October 25 announced by cablegram was found to be erroneous and withdrawn on the following day.

COMMUNICATIONS QUESTIONS AND ANSWERS.

[This department is designed especially for the use of amateurs. Beginners are invited to send in their puzzling questions. The editors will try to see that answers are given to reasonable questions but will not hold themselves responsible for the correctness of the views expressed in the communications which may find place here. All communications should be brief.]

The Dayton Astronomical Society.—Perhaps it would be of interest to the readers of POPULAR ASTRONOMY to hear of the work of the Dayton Astronomical Society. We have been organized about three years and at present we have over one hundred members, that take an active part in observing. When we first organized there were but thirteen members. Those thirteen members now are the governing body, or trustees. At the first we had the use of a 4″ refractor, but shortly we were able to purchase a very fine 6″ refractor made by the Lohmann Bros. of Greenville Ohio, with one of their automatic clocks attached. The instrument is very substantially built and the defining quality could be no better, the field being very black and the stars appear sharp and clear. And it never displays those *beautiful colors* so often seen with many instruments.

The clock working of this instrument is one of its main features. I have been able to keep an object in the field of view for twenty different observers simply by pressing the rubber bulb, and can say it has given perfect satisfaction, and all the members are more than pleased with its action. Last April we mounted an 8″ reflector of 106″ focal length, which is very good, and we are

able to use a power of 848 on either instrument, with perfectly satisfactory results. As our instruments are for the use of the public and the schools of our city, it keeps our instrument pretty busy. And this has been the cause of arousing quite an interest in this branch of science, in this section, and it is only a question of a short time until Dayton will have a good sized Scientific Hall and Observatory absolutely free to the public.

Some of our members are taking up the observations of Variable Star work, some the planets, and others the nebula. This makes observation very interesting as one always has the other to compare notes with.

Quite a few followed Brook's Comet, with good results. I believe every city should have a public observatory, and it is within the power of any one interested to form a society and purchase the instrument, so as to give those that have never had the opportunity to study astronomy, the chance to learn more about the heavenly bodies which they have gazed upon as mysteries and wonders in outer space.

I should be glad to correspond with any one who desires to form such a society, and will be glad to offer suggestions along this line.

R. E. FOSDICK.

Box 453 Dayton, O. Nov. 9, 1911.

Brooks' Comet and Venus.—Some recent notes of my astronomical activity may be of a little interest to your readers. For some weeks I have observed the movements of Brooks' Comet. I first saw it in the constellation Cygnus and have observed its progress behind the handle of the Dipper until it disappeared as an evening comet, but reappeared as visible in the morning sky, forming almost an equilateral triangle with Eta Ursæ Majoris and Cor Caroli. Yesterday morning it was bright and clear to the east of Leo, with a long tail projecting vertically upwards from the eastern horizon. A small star was visible in the telescope directly in front of the comet. The nucleus was very bright, and the tail clear, narrow and outlined for a considerable distance. The tail was much narrower than the tail of Halley's comet, and I think slightly brighter. The remarkable verticalness of the tail yesterday was striking.

The question has often been asked, does Venus ever cast a shadow? Yesterday morning that planet cast a shadow most noticeably. The window of an eastern room in my home was clearly projected on the side wall, and I verified the cause of the shadow to be Venus by placing my eye all round the margin of the shadow, and saw that nothing except the planet could have cast it. I held my hand a little way off from the wall and Venus cast a sharp and distinct shadow of my hand on the wall also. The brilliancy of Venus these mornings is very intense.

Last Saturday evening I saw two meteors. One was in Cetus and was travelling westward. It much resembled a rocket, its motion was not quite straight in my judgment, and it occupied about three seconds in its flight of about fifteen degrees. That was about 7:30 P. M. An hour later I saw a most remarkable one a little to the west of Gemini. It was singularly bright and very white, my sister who noticed it at the same time calling my attention to its unusual brilliance which I was on the point of remarking.

This summer I have made a number of mirrors for reflecting telescopes, all a little larger than six inches in diameter. I find that I can bring a mirror to an approximate nearness to complete correction in a very short time now. By a very simple method which I have adopted, also by hand, I have polished

and figured a six and one quarter inch mirror of about fifty inches in focal length in about three or four hours. This is a remarkable improvement on the days and days of work which perfecting a mirror formerly occupied.

Saturn and Mars are both very interesting objects these nights, and occupy many a profitable glance in the telescope.

We have a Government Observatory here, but owing to its antediluvian methods, the public seldom see through its telescope. Frequently I have gone thither on fine starry nights to view the heavens but always met with repulses. They have a splendid building but as far as supplying popular requirements is concerned they are as far behind the times as Patagonia or China. Hence I have had to construct my own telescopes or dwell passively oblivious of all the vast and splendid wonders of the heavens.

ALBERT R. J. F. HASSARD, B. C. L.,
9 North Street, Toronto, Canada,
October 31, 1911.

Satellites with Retrograde Motion; Question.—On page 541 of POPULAR ASTRONOMY for September 1911, Professor See refers to the retrograde motion of satellites of Jupiter and Saturn. Will you kindly state what satellites of these planets retrograde and who discovered that any of them do.

ANSWER. Phoebe, the ninth satellite of Saturn was discovered by Professor W. H. Pickering in March 1899. The fact that its motion was retrograde was also discovered by W. H. Pickering in 1904 (Harvard Annals Vol. LIII, No. III) and completely verified by Frank E. Ross (Harvard Annals Vol. LIII, No. VI.)

The sixth and seventh satellites of Jupiter, discovered in 1904 and 1905 by C. D. Perrine at the Lick Observatory, were at first thought to be moving retrograde but the elements computed by Mr. Ross show that their motion is direct (Pub. Astr. Soc. of the Pacific Vol. XVIII p. 80; Monthly Notices R.A.S. Vol. LXVII p. 272).

The eighth satellite of Jupiter was discovered by Melotte at the Royal Observatory at Greenwich in 1905. Elements calculated by Messrs. Crawford and Meyer indicate that its movement is retrograde (Astr. Nach. Band 179, p. 379.)

Morning Sky on October 4.—To the early risers, at this place, (Liberty, Ind.) on the morning of October 4th 1911, at 5 o'clock, a naked eye scene presented itself in the eastern sky which was most beautiful and rarely witnessed. Directly east about ten degrees above the horizon appeared Beljawsky's comet, a ruddy little object with a broad and lengthy tail. About 30 degrees north of Beljawsky's comet could be seen the familiar Brooks' comet *c* 1911, with its slender lengthy tail. A little south of east near the horizon could be seen Mercury, which by the aid of a small telescope showed a gibbous form. Then perhaps 18 degrees above the horizon silvery Venus shone in beautiful crescent form (with telescopic aid). High up, and a little to the west of the zenith could be seen Mars and Saturn among some of the grandest constellations of the heavens, Orion, Pleiades &c. &c.

Thus with a singularly clear sky two comets and four planets (beside the earth) could be seen at a glance. In a lifetime of three score years the writer does not recall a more sublime spectacle in the skyward vault.

ISAAC N. SNYDER.

Halley's Comet; Question.—Please answer the following questions concerning Halley's comet during its last apparitions: What was the diameter of the head in miles; velocity during perihelion; length of tail in miles; when last seen by telescope?

ANSWER.—The actual dimensions of so hazy an object as a comet are difficult to determine within narrow limits, but a measure of the halo around the head of Halley's comet, made by Dr. Aitken at the Lick Observatory in December 1909, gave a diameter of 15′, which at the distance 1.36 astronomical units amounts to 550,000 miles. The photographs taken by various observers yield different results according to the length of exposure and manner of developing the plates. The following tables give the results, as determined by Dr. Curtis at the Lick Observatory for a number of selected dates (See Pub. Astr. Soc. of the Pacific No. 132, June 1910):

HALLEY'S COMET.

Diameter of Head		Length of Tail.		
	Miles			Miles
1909 Sept. 12	13,000	1909 Dec. 16	3′ =	430,000
Dec. 14	220,000	1910 Jan. 28	1° =	4,700,000
1910 Jan. 7	79,000	Feb. 4	1.7 =	8,800,000
28	181,000	Apr. 21	4 =	9,200,000
Feb. 4	141,000	30	14 =	19,000,000
11	170,000	May 5	28 =	27,800,000
28	153,000	10	38 =	24,400,000
Apr. 19	129,000	17	105 =	18,900,000
28	118,000	19	146 =	18,600,000*
May 1	122,000	23	59 =	16,000,000
5	161,000	28	28 =	17,600,000
23	194,000	June 2	20 =	21,000,000
31	315,000	July 1	4 =	18,000,000
June 2	308,000			
8	340,000			

* Visual determination.

The velocity of the comet when at perihelion was about 34 miles per second.

As to the latest observation we are not sure that we have a correct memorandum, but the comet was observed by Barnard at Yerkes Observatory April 25, 1911 and was photographed by Curtis at the Lick Observatory May 27, 1911.

NOTES FOR OBSERVERS.

A Planetary and Lunar Section.—Mr. Latimer J. Wilson of Nashville, Tennessee, writes that a Planetary and Lunar Section of the Society for Practical Astronomy has been formed and that he has been made Director of the section. He invites all amateurs who are interested to join the society and become members of his section.

We are glad to see this new step toward getting amateurs to work at something definite and hope that many who have telescopes of sufficient aperture will join in the very fascinating study of the planets.

The first Monthly Report of the American Association of Variable Star Observers.—The growth of this Association since the initial notice of its formation in the November issue of "POPULAR ASTRONOMY" has been most encouraging. Fifteen observers are now coöperating in this work. The new members are as follows:—

Mr. M. W. Jacobs, Jr. Harrisburg, Pa.
Mr. Harold Bunker, New York City.
Mr. J. C. Bohmker, Chicago, Ill.
Dr. Caroline E. Furness, Director Vassar College Observatory, Poughkeepsie, N. Y.
Mr. Frank E. Hathorn, Des Moines, Iowa.
Miss Helen M. Swartz, South Norwalk, Conn.
Rev. Tilton C. H. Bouton, Hudson, N. H.

In submitting a report of the work of this Association, the first consideration was to afford thereby a means of comparing the observations made by the observers during the month, so that the estimates of the light value of any star that several were observing could be seen at a glance and easily compared.

There are various ways of arranging the material submitted to facilitate these comparisons, but as economy of space is a prime consideration it is hoped the present arrangement will prove satisfactory to those interested.

Where a member of the association is the sole observer of a certain star, and hence no comparison of observations is possible, the estimates are given in the hope that they may be of some service to foreign observers of variable stars, and others in this country who are not as yet coöperating with us.

For the benefit of those who are just starting in on this work the writer offers the following suggestions: The chief difficulty at the outset is the matter of identifying the variable. If the position of the variable is not indicated on the Star Atlas used, the observer should supply the omission by plotting its position. A tracing should then be made of the naked eye stars in the immediate vicinity of the variable so that with this in hand the location of the fields should be greatly facilitated.

It is very important to so hold the chart of a field that it presents the telescopic view at the time of observation. When the star is rising hold the chart with the north point at the right hand, when the star is low in the west the south point should be at the right hand, hence the south point is uppermost when the star is on the meridian.

Messrs. Jacobs, Gray, Hunter, Vrooman, Bohmker, and Olcott are members of the Variable Star Section of the Society for Practical Astronomy, an organization founded recently by Mr. Frederick C. Leonard, of Chicago, Ill., which is doing good work and worthy of the support of all amateur astronomers.

The lists of estimates follow, the observations dating from October 10 to Nov. 10, excluding the observations of stars too faint at present to be observed in small telescopes, so that the data here given is by no means indicative of the number of observations made by the members of the association during the time specified.

After the observer's name, the aperture of the telescope used is indicated. Unless otherwise stated the instrument is in each case a refractor.

The rows of figures, from left to right, under the observers names, are the dates of the observations, below which appear the estimates of the light values of the variable stars expressed in tenths of a magnitude.

The feature star of this report is beyond question that wonderful variable

VARIABLE STAR OBSERVATIONS.

Oct. 10 to Nov. 10, 1911.

	Olcott 3″											Jacobs			Vrooman					Hunter		Miss Young					Miss Swartz					Hathorn 3″
	10	12	13	16	23	24	26	28	29	2	7	16	23	29	14	18	19	22	28	16	23	23	24	25	2	7	24	25	26	27	7	31
ST Andromedæ	9.3			9.3	9.3					9.2										9.2												
V Andromedæ	9.6																												8.8			
R Aquarii			9.5			9.5															9.6											
T Aquarii			9.1			8.5									9.3		8.4															
W Aurigae						9.5			9.2			8.7	8.7																			
R Camelopard.	9.2			9.0	9.0		9.2			9.0	8.8	8.7	8.8																		
V Camelopard.		9.0			9.3					9.4																						
T Cephei	6.5				6.7			7.1				7.4	7.8		7.4			7.4														
o Ceti					7.5											7.2													7.3			
R Coronae	10.5		9.8	10.0								9.6	9.6	9.0																	
R Cygni		9.6			8.4					7.4	6.8				9.0		8.8								8.4		9.8					
U Cygni						9.5				9.0		9.8	9.5														9.0				7.2	
X Cygni		6.1			7.0					7.3		7.1	7.4														10.0		9.0			
R Draconis	9.6			10.2									10.8																		
T Herculis		10.8																					10.7		11.0							
S Lyncis						10.2			9.8																						
W Lyrae		8.9		8.5		8.1		7.8		8.0	8.1																				
Z Ophiuchi			9.7																			8.0		7.7	7.6						
R Pegasi		8.4			8.7		8.8			8.9	9.0											8.6		8.7	8.7						
W Persei		9.0			9.2																8.9										
R Scuti				6.1			6.5																								
W Tauri						9.5			9.8																						
R Vulpeculae		8.0				8.2			8.3			8.4	8.3									9.2			9.2						

	Jacobs 3″						Miss Young					
	16	23	24	29	30	2	14	24	25	28	2	7
RU Andromedæ			11.2		10.7							
R Aurigæ		9.9		10.0				9.0				9.3
S Boötis				10.8		10.4						
S Cassiopeiæ		8.5		8.4								
T Cassiopeiæ			10.4	11.1				10.0				
V Cassiopeiæ			11.6	11.4								
W Cassiopeiæ		9.7		9.9								
S Cephei		10.4		10.4								
X Coronæ	10.0	9.7		9.6								
RS Cygni		8.2		8.1								
SS Cygni		12.0		8.3		9.0	11.9	11.8	11.7	9 0	9.4	11.3
S Herculis				11.1								
R Lyncis		10.5		10.0				10.2			9.8	
R Urs. Maj.		8.1		7.8					7.9		7.4	7.5
S Urs. Maj.		8.1		8.0					7.6		7.3	7.6
U Urs. Min.		10.5		10.7		10.8						

	Vrooman 5″			Hunter 5″		
	14	22	28	22	23	24
R Andromedæ						10.2
RR Andromedae			10.1		10.2	
R Cassiopeiæ			10.7			
T Draconis	10.3	11.1				
Y Persei				10.4		

	Miss Young 8″						Miss Swartz 3″		
	23	24	25	28	2	7	13	26	
T Andromedæ	10.8				10.4				
S Aurigæ	8.8					8.7			
Z Aurigæ		11.0				10.5			
S Camelopard	9.3					8.9			
X Camelopard	12.5								
U Can. Min.				9.1					
T Can. Ven.				9.1					
X Cassiopeiæ		9.7							
RZ Cygni			12.5						
SX Cygni			12.9						
S Delphini	9.9				10.0				
U Herculis	10.7								
W Herculis	8.6					8.8	8.3		
R Lacertæ	8.9					9.5			
S Lacertæ	8.5					9.0			
R Leonis				8.8					
S Leonis				10.5					
W Leonis				12.0					
R Orionis		13±							
U Orionis	12.3								
RT Pegasi	9.6								
R Persei								8.3	
SU Tauri	9.5					9.4			
R Trianguli	5.8				6.0	6.2			
T Urs. Maj.			12.4						

SS Cygni. A very striking comparison is afforded by the observations of Miss Young, and Mr. Jacobs. These show that at some time between the 25th and the 28th of October, this star increased three magnitudes in brightness. It was as if Castor in that interval of time had attained the brilliance of Sirius. By November 7, only ten days later, SS Cygni had decreased in brightness two magnitudes.

Space does not permit of further comment, but the peculiarities of this variable are sufficient in themselves to commend variable star observing as a fascinating line of observational work.

WILLIAM TYLER OLCOTT.
Corresponding Sec'y.

Norwich, Ct. Nov. 10, 1911.

Work for an Amateur.—It is frequently desirable to determine the quality of a telescope. An indication as to the degree of perfection of the lenses in the case of a refractor, and of the mirror in the case of a reflector, is the possibility of seeing separately objects which are very close to each other. The objects usually used for this purpose are pairs of stars, since there are pairs ranging from a distance so small that they cannot be separated visually with even the largest telescopes to a distance large enough to be apparent to the naked eye.

For the convenience of makers of telescopes and of those who have small telescopes of their own it would be very desirable to have at hand a list of such objects whose positions are known so that they could easily be found, and whose distances from each other also are known so that they might furnish information as to the possibility of separating objects with the instrument in question. From the list of 13,000 or more double stars published in Burnham's "General Catalogue of Double Stars" it would be possible to select forty or fifty pairs suitable for this purpose. It would merely be necessary to search through the volume for pairs which have certain characteristics. First, it would be necessary to select those whose motion relative to each other is slight, or obviously the list would in a short time be unreliable. Second the star should not be fainter than the eighth or ninth magnitude and the components should be nearly of the same brightness. Third, the distance between the stars need not be less than 1″ of arc or more than 5″ of arc. Fourth, the stars of the list should be scattered through the whole twenty-four hours of right ascension so that some of them might be available at any time of the year.

Any one who may desire to prepare such a list should communicate with the editor for further suggestions as to the method of procedure. The list when satisfactorily made, could be published in POPULAR ASTRONOMY.

GENERAL NOTES.

Professor Ernest W. Brown, of Yale University, has been elected an honorary fellow of the Christ's College, Cambridge. (Science Nov. 17, 1911.)

Dr. Otto Bergstrand has been appointed professor of astronomy and director of the observatory at Upsala. (Science Nov. 17, 1911).

Professor W. W. Campbell, Director of the Lick Observatory has returned to Mt. Hamilton after an absence of several months in Europe. While in Europe Professor Campbell was seriously ill for several weeks, but he has so far recovered that on his return to Mt. Hamilton he was able to drive his own automobile up the mountain, no easy task even for a person in perfect health.

We are indebted to Dr. R. H. Curtiss, acting Director of the Detroit Observatory, Ann Arbor, Mich., for the following two items.

Professor W. J. Hussey, who left Ann Arbor in June to assume the Directorship of the Observatory of the National University of La Plata, Argentina, is engaged in the reorganization of the scientific work of that institution and is prosecuting his own researches in the field of visual double stars with gratifying results. Professor Hussey retains his connection with the Observatory of the University of Michigan and is developing the plan of coöperation in astronomical work between the Universities of Michigan and La Plata announced earlier in the year.

New Thirty-seven-inch Reflector of the Detroit Observatory.—Apropos of the list of large reflectors published in your journal last month it may be in order to state that the new 37½″ Reflector of the Detroit Observatory of the University of Michigan was completed last May and has been in constant use ever since in the Cassegrain form with single prism spectrograph.

New Observatory at Setif, Africa.—The new observatory in Africa referred to on page 552 in our October number has been located in the vicinity of Sétif, Algeria. It is under the direction of M. Jarry-Desloges, and observations were begun about the end of September. The coördinates of the observatory are:

Latitude + 36° 11′ 19″ Longitude 3° 04′ 21″ east of Paris Altitude 1113^m

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The Brightness of Betelgeuse.—Measures of the light of this well-known variable star have been taken with the selenium photometer at this observatory since September 1910, and it is hoped that the character of the fluctuations will be definitely established. Betelgeuse has decreased about 0.25 mag. since September 29, 1911, and is now 0.2 mag. brighter than Aldebaran. From the steady change of the variable, it is probable that a minimum will be reached in December, when the two stars will be nearly equal in light. This was the case in the two minima observed last year. It may also be expected that Betelgeuse will grow brighter again before Orion disappears in the west next spring.

JOEL STEBBINS.

University of Illinois Observatory.
Urbana, Illinois. Nov. 13, 1911.

Astronomical and Astrophysical Society of America.—Circular of Information. The thirteenth meeting of the Astronomical and Astrophysical Society of America will be held at the Carnegie Institution, 16th and P Streets, N. W., Washington, D. C., on Wednesday, Thursday and Friday, December 27-29 1911.

This particular time and place have been chosen for an extra meeting for the purpose of bringing the society, both as individuals and as an organization into closer touch with the American Association for the Advancement of Science which holds its convocation week meetings in Washington, D. C., beginning on December 27, 1911.

A joint session with Section A of the American Association for the advancement of Science has been arranged for Friday morning as described in the program below.

A meeting of the Council of the Astronomical and Astrophysical Society of America is called for Wednesday, December 27, at 9:15 A.M. in the Arlington Hotel.

PROGRAM.

Subject to modification by the Council, the program will be as follows:

WEDNESDAY DECEMBER 27—

10 A. M. to 12:30 P. M.—Papers.

2:00 to 4:00 P. M.—Papers.

8:00 to 10:00 P. M.—Reception at the Naval Observatory tendered by the Superintendent and Staff to the Officers and Members of the Society. (To reach the Observatory take cars of the Washington Railway and Electric Co. marked Georgetown, and transfer at Wisconsin Avenue.)

THURSDAY DECEMBER 28—

10:00 A. M. to 12:30 P. M.—Papers.

2:00 to 4:00 P. M—Paper and Committee Reports.

4:00 to 6:00 P. M. Visit to the Astrophysical Observatory of the Smithsonian Institution.

FRIDAY DECEMBER 29—

9:30 A.M. to 12:30 P. M.—Joint Session with section A of the American Association for the advancement of Science. The program of this session will include the address by the retiring chairman of Section A, Professor E.H. Moore; a paper on the "Asteroid Problem" by Reverend J. H. Metcalf; and probably also a paper by Professor Lewis Boss on his recent stellar researches.

2:00 to 4:00 P. M.—Papers and Business.

Abstracts of Papers, presented at the Ottawa meeting of the American Astronomical and Astrophysical Society.

ON SCALES OF INTENSITY FOR THE LINES OF THE SOLAR SPECTRUM.
BY FRANK W. VERY.

A spectral line not appreciably broader than an image of the slit, and perfectly black, may be rated as 10 on an absolute scale of intensity, and the strength of any line in absolute units is the product of its width by the intensity of its absorption, multiplied by a constant. The constant may be chosen so that unity coincides with Rowland's unity, and it is found that in this case the above definition is very closely fulfilled, although Rowland's numbers diverge considerably in other parts of the scale.

From a smooth curve which represents the true photometric intensities of ultra-violet lines on negatives by Higgs, the significance of Rowland's symbols has been found to be as follows:

$R_{0\,1} = 0000 = .05$	$R_1 = 1.05$	$R_5 = 8.40$	$R_9 = 17.05$	$R_{13} = 25.70$
$R_{0\cdot 2} = 000 = .15$	$R_2 = 2.57$	$R_6 = 10.60$	$R_{10} = 19.20$	$R_{14} = 27.85$
$R_{0\cdot 3} = 00 = .25$	$R_3 = 4.30$	$R_7 = 12\,80$	$R_{11} = 21.40$	$R_{15} = 30.00$
$R_{0\cdot 4} = 0 = .35$	$R_4 = 6.30$	$R_8 = 14.95$	$R_{12} = 23.55$	

These values have been confirmed by measures in the green.

It is shown that the method of measurement employed by Professor Pickering in Harvard *Annals* (Vol. 8, pp. 207-219) is an imperfect one, yielding intensities which may be made to agree with absolute values through a middle range, but which are discordant at the ends of the scale; and, in general, the relation between the width and the intensity of the photographic images of spectral lines is not as simple as has been assumed. It is also shown that differences of width of spectral lines have been exaggerated in Thollon's Atlas, doubtless in order to convey a more realistic impression of the intensities.

Periods of Variable Stars in the Small Magellanic Cloud.
BY MISS HENRIETTA S. LEAVITT.

The periods of 25 of the variable stars in the Small Magellanic Cloud have been determined, and have been found to vary in length from 1.25336 days to 127.0 days, while the light curves are of the cluster, sometimes called the "ant-algol" type. The brightness and the length of the period are so closely related that if one is known, the approximate value of the other may be inferred. For an increase of one magnitude in brightness at maximum or minimum, the logarithm of the period increases by about 0.48. It seems possible that all these variables are of similar mass, those whose periods are long having slight densities, and vice versa. On account of their faintness, it is impracticable to obtain their spectra, with our present facilities. A number of brighter variables having similar light curves, as UY Cygni, are in isolated positions, and should repay careful study not only of their spectra, but if possible, of their parallaxes. Among other questions suggested are the following:

(1) Are there definite limits to the mass of variable stars of the cluster type?

(2) Do the spectra of such variables having long periods differ from those of variables whose periods are short, and how?

Short Formula for Computation of Circum-meridian Azimuths.
BY C. C. SMITH.

A short formula for the computation of azimuths observed near the meridian is here given. The ordinary formula for azimuth requires the use of a subtraction logarithm. In the short formula $1 + \cot\delta \tan\phi \cos t$ is expanded in a series and after rearrangement and reduction gives a formula for azimuth which requires the looking up only of the natural logarithm of the declination after which the mutiplications may be quickly carried out on the arithmometer. The formula is much shorter and gives less chance for error than the ordinary formula, especially where a considerable number of observations have been taken at each station.

Changes in Collimation and Level of the Ottawa Meridian Circle.
BY R. M. STEWART.

This paper deals with the observations made at Ottawa from March to December, 1910. Measurements of collimation and level were made usually twice in the course of an evenings work; the changes during the interval (four hours on the average) are here investigated. The average change of colli-

mation was +".03 for Clamp East and —".20 for Clamp West; these changes run with great regularity, changing invariably with the reversal of the instrument, and appear to be entirely independent of seasonal and temperature changes or of the interval between the observations. The changes of level were not sensibly affected by reversal of the instrument, but there is some evidence of small seasonal effect.

PRELIMINARY MEASURES OF THE SOLAR ROTATION.

BY J. S. PLASKETT.

This paper is a first contribution towards the scheme of coöperation in determining solar rotation by the Doppler displacement of the spectral lines, which was organized at the meeting of the Solar Union at Mt. Wilson last September. A large amount of preliminary work, which is briefly described, has been performed for the purpose of ascertaining the most suitable apparatus and methods for accurate work. The mean of 14 rotation plates, obtained in June and July of the present year, gives, at the equator, a velocity of 2.035 km., about 1% less than Adams' values. The measures of upwards of 40 spectra, in the region allotted to this Observatory, λ 5500–λ 5700, give no definite indication that the velocity due to any particular lines or elements differs from that of the general reversing layer. Further measures of plates, having impressed upon them an arbitrary displacement of the same magnitude and character as the rotation plates, show that the small varying displacements of different lines is of the same order as those obtained above and is probably mostly due to the character for measurement of the line itself and not to differences in the velocity.

Star Clusters and Nebulae.—More than two thousand years ago the Greek philosophers, Democritus and Anaxagoras assured their countrymen that the luminous circle of the Milky Way consisted of nothing but dense masses of stars too small and too close together to be seen separately. The former, sometimes known as the "Laughing Philosopher" of Greece, also entertained some equally remarkable views on other subjects: the atomic theory, the nature of the sun and stars, and so on, many of which have been verified by the later investigation.

In addition to the Milky Way itself there are to be found, scattered all over the sky, luminous patches of cloud-like material, stellar groups, or "nebulae," as some of them are called. As instruments have improved Mr. F. W. Henkel points out in "*Knowledge*" for September, so more and more of these have been resolved into separate stars, but no telescope ever can or will resolve the true nebula since it is not composed of stars.

The Hindu-Arabic Numerals, by David Eugene Smith and Louis Charles Karpinski, published by Ginn and Company. This is a neat little volume of 151 pages which should be on the desk of every teacher of higher mathematics. It gives an interesting account of the origin of the numerals which we use in ordinary life today, of their introduction into Europe, their gradual adoption by the different nationalities, and the gradual changes in form of most of the numerals.